A Personalised
Adaptive Learning System for Students

EI Working Paper Series - Issue 3

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Educational Initiatives (EI) believes that significantly improved student learning can happen only through systematic research into learning which includes assessment, as well as areas like misconception research. This working paper series will share learnings from various past and present EI projects as well as path-breaking work in these areas elsewhere in the world. Please write to us at assessment@ei-india.com for questions or comments.

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WHY THIS PROJECT HAS LARGER RELEVANCE

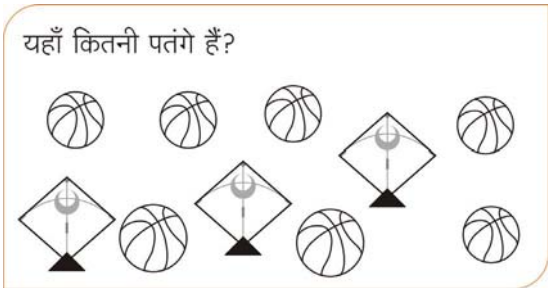
It is being increasingly understood and accepted that the quality of learning across a vast number of schools in the country today is unacceptably poor. The problem exists at two levels – one, students are often not developing even the basic literacy skills like reading, counting, etc., and two, the little learning that happens tends to be procedural or 'mechanical' learning – students are able to follow taught procedures but have not understood the underlying concepts. Studies conducted by Educational Initiatives (EI) indicate that these problems afflict almost all 'schools for the poor' – government-run as well as the so-called 'low-cost private schools.'

The goal, clearly, is to provide quality education and at scale. We want children to master basic competencies, learn with understanding and be able to think independently even though severe constraints exist in terms of teacher availability and quality, multi-grade classrooms, etc.

Theoretically, technology can be a useful tool to achieve quality at scale, as demonstrated by the telecom revolution and some early success stories in e-governance, rural banking, etc. Yet, the ground reality suggests that e-learning – not only in India but even internationally, has been high on promise and low on demonstrated achievement. The solutions tend to be technology-driven and educationally weak. We present here a solution – Mindspark - we believe is *educationally-rich* and *technology-supported.* It is a computer-based, adaptive learning solution designed to allow the child to learn at her own pace and to serve, wherever possible, to *supplement*, not replace classroom teaching. The system is currently being used for Maths learning and early results have been very encouraging. A language Mindspark system is currently under development and trial.

LEARNING LEVELS IN MATHS IN GOVERNMENT SCHOOLS

Our primary area of work in EI is in large scale assessments and a significant part of that work happens in 'schools for the poor', many of them government-run schools in rural and urban areas. Studies conducted by EI and other education assessment organisations such as Pratham (ASER) and Azim Premji Foundation (APF) show that the learning levels in these schools are extremely low. Following assessments, EI conducts 'student interviews' which provide unique insights into *why* students face specific difficulties in certain topics. Now, Mindspark trials themselves are logging detailed data about the same. EI's Municipal School Benchmarking Study (which covered 30 towns in 5 states) and the Andhra Pradesh Randomised Evaluation Study (APRESt, which tracked 50,000 students over 5 years) clearly show that basic skills in number concepts and operations do not develop at appropriate class level and often even beyond. Some examples are shown alongside, while the most common difficulties faced by students are discussed below:



This question ('How many kites are here?') tests the counting ability of class 2 students. It was correctly answered by only 55% of 10,000 students who were asked even though the question was read out. Source: Andhra Pradesh Randomised Evaluation Study, 2008

Language as a roadblock to learning Maths concepts: Without basic language skills, acquiring basic Maths concepts is difficult. During Mindspark trials in rural and municipal schools, it was found that the biggest hurdle in learning Maths was not just the lack of understanding of Maths, but also the inability to read properly. Even Class 5 students were not able to read simple questions like "कितने फूल हैं?' (*How many flowers are there?).*

Class	Question	Correctly answered	Sample Size
4	What is 1 ten and 5 hundreds?	14.6%	9511
6	Solve: 713 x 24	34.9%	7114

Performance on two questions asked to municipal school students is shown above. While the first question uses a slightly unfamiliar form (the correct answer – 510 – should be known even at class 3), the second question is a straight-forward multiplication. Source: Municipal School Benchmarking Study, 2007 and Andhra Pradesh Randomised Evaluation Study, 2008'.

Basic number skills: Studies show that many students who can recite the numbers from 1 to 100 have not actually understood the value of numbers. For instance, many students who can 'count till 100' are not able to answer whether 61 is bigger or 39 even at class 4 and 5 levels. As per the ASER 2008 (rural), only 21.4% students of Class 3 could recognise numbers from 1 to 9 and only 34.4% students of the same class level could recognise numbers from 10 to 99.

Number conservation: This is the understanding of the concept that grouping a set of discrete objects does not change their count and should be developed by the age of 4 or so. EI studies routinely find students who, when first shown a bunch of sticks and then the same sticks spread out, say that the spread-out sticks were *more in number* than the bunched ones!

Understanding zero: Often students are unable to understand that 'nothing' is the same as zero. They were unable to connect this to the numeral zero as well as the word 'shunya' (Hindi for 'zero'). For instance, when asked how many birds were left on a branch after all of them flew away, they were able to answer 'none', but could not connect it to zero (even from among a set of options given).

Place value issues: Place value is a major stumbling block for many children. Many tend to write "दो सौ पंद्रह" (two hundred and fifteen) in numerals as "20015." Inability to understand this concept also becomes a hurdle in understanding operations eventually.

Skills in number operations: The inability to understand place value concepts eventually hampers the development of operation skills. As per the ASER Report, 2008, only 32.8% and 37% of Class 5 can subtract and divide respectively. The APRESt question shown above also points in the same direction.

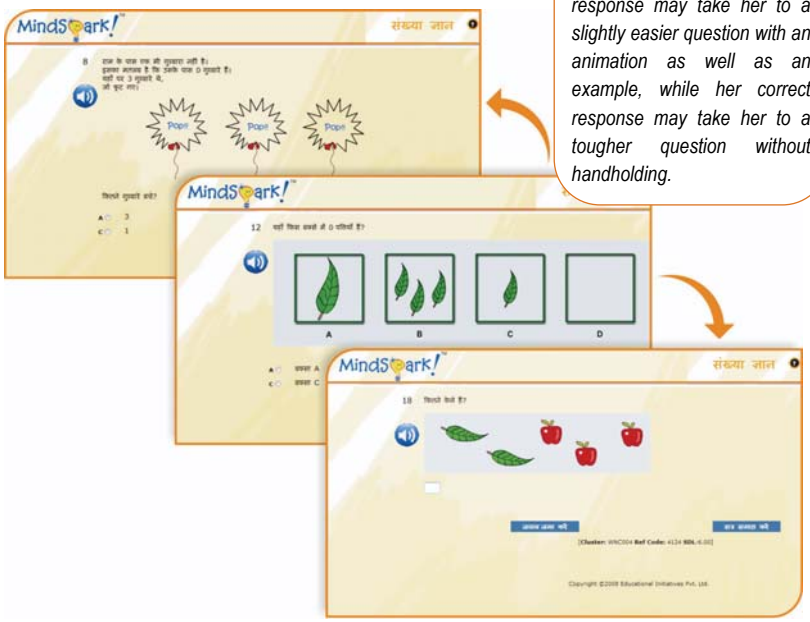
The above points are being noted because an effective e-learning system has to specifically tackle known educational problems like these.

WHAT IS MINDSPARK?

Mindspark is a computer-based, personalised adaptive learning programme. This means that it allows each student to learn at the pace she is comfortable with. Mindspark is based on the belief (reinforced by experiments worldwide) that students learn best when they control the pace of their own learning.

Mindspark has an intelligent adaptive logic which decides whether the student should be allowed to move ahead in a concept or not. For instance, in learning about the meaning of 0, the student's wrong response may take her to a slightly easier question with an animation as well as an example, while her correct response may take her to a tougher question without handholding.

- **Finely-graded questions:** In Mindspark, the student is not learning passively by listening to someone, or viewing ready-made solutions, but learning interactively by answering questions or doing small activities of progressively increasing complexity. The questions and tasks are very *finely-graded* to ensure that students learn as they answer and move gradually to higher levels. This makes sure that the child is truly thorough with an idea before moving on to the next.



Mindspark's finely graded questions make sure that the child moves from the known to the unknown with ample support – through a series of questions. Starting questions on a topic may introduce the concept through an animation, while later questions would require the child to demonstrate much deeper understanding of the idea. However, this progression is very gradual. Explanations and remedial support are provided when a child fails to answer correctly after a number of attempts.

- **Adaptive logic:** Mindspark uses a complex adaptive logic to decide what problem to serve up to a student next, based on her response to the current problem and problems answered earlier. Thus, the system does not allow a child to move up to higher levels without a strong understanding of the basics. This helps students below class level to come up to their class level. At the same time, Mindspark is a boon to academically strong students – those who are performing at a higher level than their class level -- as it provides challenging problems to such students allowing them to stay engaged and occupied and enabling them to learn more.
- **Focus on understanding:** Mindspark's focus is on understanding and analytical thinking, not just knowledge of facts or procedural drill. Many e-learning programmes focus on procedural fluency rather than on conceptual understanding or application. The very nature of the Mindspark programme however, emphasises *understanding,* for example, the concept of area in multiple ways, rather than merely remembering formulae.
- **Voiceovers to help overcome language roadblock:** As students in rural and municipal school setups often have weak reading skills, Mindspark makes sure that this does not become a roadblock in students' Maths learning. Each question is equipped with a voiceover button which the student can enable if she has difficulty in reading the question on her own. For private school students, voiceover support is provided up to class 2.
- **Modules co-ordinated with class syllabus:** The Mindspark programme covers the entire Maths content for classes 1 to 10. Within each topic, concepts are covered to their full depth, keeping not only the curriculum in mind, but also important skills related to that topic which may or may not be stressed upon in the textbook. The teacher is expected to activate topics in sync with the concepts being taught in class and retains overall control over what the children do.
- **Detailed feedback and reports:** Teachers play a key role in helping the student learn efficiently. In order to help parents and educators track a student's progress at any time, detailed progress reports are available at all times. These reports not only provide a summary of the progress made by each student of the class, but also give details of difficulty areas for an individual student or a group of students.

A number of reports are provided to allow teachers to closely monitor student progress. These allow a teacher to get an overview of the progress of the class, details of the progress of specific students as well as question or skill level details – say, specific questions the entire class has found difficult. Mindspark also alerts teachers about specific cases where students do not seem to understand a concept and may need individualised attention.

PILOT STUDIES

Two pilot studies have been conducted to track children's progress in terms of learning improvement after using Mindspark. The Ratlam Pilot was conducted in Isarthuni village of Ratlam district with the support of Suzlon Foundation. Later, the Bombay Municipal School Pilot was conducted at the Bajaj Municipal School, Kandivalli, Mumbai for Naandi Foundation. The Michael and Susan Dell Foundation provided financial support and McKinsey & Co. was an observer.

To measure the improvement in learning due to Mindspark, pre- and post-tests were conducted before and after the trial period in both projects. Moreover, to make sure that the increment found in the students' learning (if at all) was largely a result of doing Mindspark, the students who were not doing Mindspark in the Mumbai pilot were asked to also take the same pre- and post-tests in order for them to act as a control group. The test used was a standardised paper for which learning data of municipal school children across 5 states was available. Two groups of English-medium private school students were also tested to know their comparative level.

Projects at a Glance

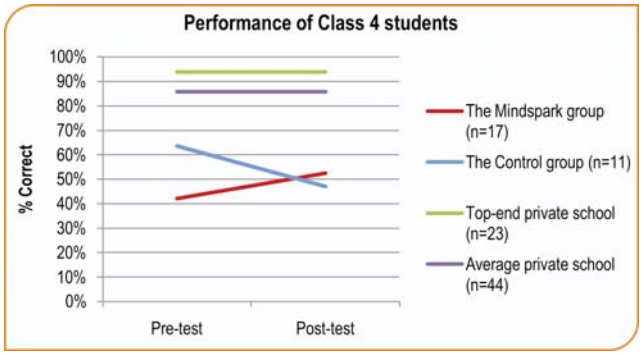
Project	Dates	Number of Students	Classes	Mindspark Sessions	Topics
The Ratlam Project	Sept 18, 2008 to Oct 1, 2008	25	3, 4, 5	7 sessions of 25 minutes	Whole Number Concepts, Whole Number Operations
The Mumbai Municipal School Project	Jan 27, 2009 to Mar 14, 2009	40	4, 5	19 sessions of 30 minutes	Whole Number Concepts, Whole Number Operations, Fractions

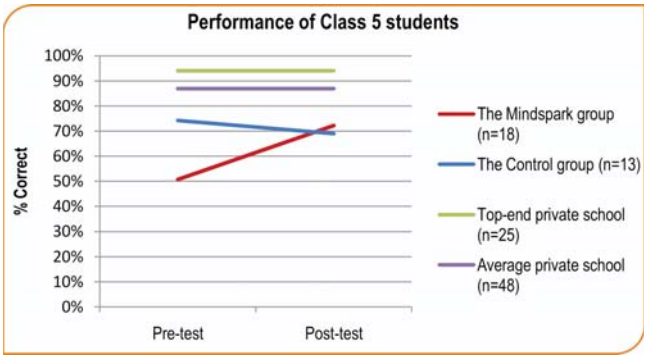
IMPROVEMENT IN LEARNING

It must be pointed out that the class 3-5 students of the pilot studies engaged with Mindspark at the level of kindergarten and class 1 topics. Even in those topics, learning levels were initially very low. Mindspark was found to bring about a positive change in students' learning levels. A comparison of the pre- and post-test scores in the Mumbai trials shows a statistically significant positive improvement in student learning – an increase of over 34% on the existing learning base. The improvement in student scores in the Ratlam project was to the tune of 90% on an extremely low learning base.

Improvement in scores observed in the pre- and post-test in the Mumbai Municipal School pilot. The graph shows that some students showed remarkable gains while others showed modest gains.

To check how these compared to the performance of elite private schools, EI tested Class 4 and 5 students in two private schools too. One was a 'top-end' private school with small class sizes and excellent facilities, while the other was a more average private school. The comparative performance of students of these private schools, the students doing Mindspark at the Mumbai trials and students of the control group is given below.





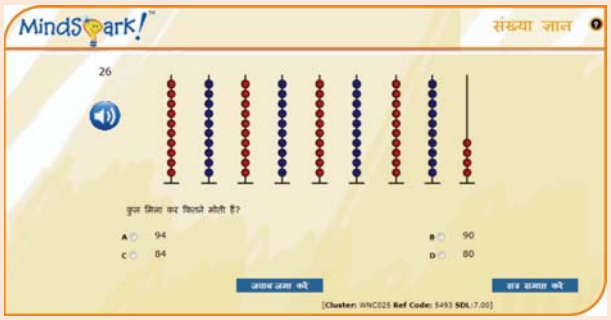
The graphs represent the low levels of learning of students of the Bajaj School in Mumbai and the improvement in their learning due to Mindspark. However, to reach their current class level as represented by the levels of private school students, they would need intervention for a longer period of time.

Caveats: The caveats to be kept in mind are that the number of students tested was small and that the duration of the pilots was 2 weeks in one case and 7 weeks (which is about half a regular school term).

The confidence that Mindspark is helping learning improve significantly comes not only from the data above, but also from observational evidence (presented in the next section), the experience of private English medium schools who are using the programme and feedback from students and teachers. However, longer pilot studies are also planned covering more students to collect more evidence of the same. The studies mentioned covered only Maths, whereas it is felt that student learning will improve even more from a simultaneous pilot covering both language and Maths, considering the low language levels of the students. A number of improvements were also made in the system based on the learnings in these two pilots, which is also likely to be a continuing trend.

OTHER EVIDENCES OF IMPROVED LEARNING

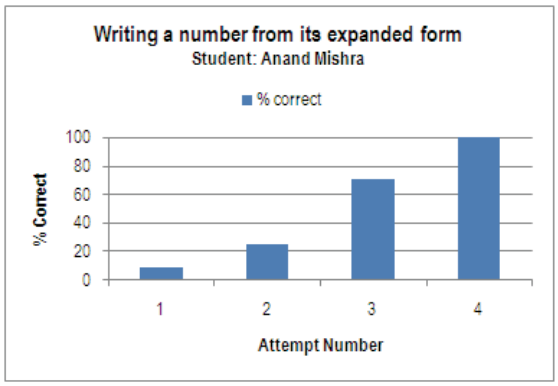
Apart from the data, a number of observational evidences suggest that Mindspark has been successful in improving the learning levels of many students. Here is the specific instance of one student who was struggling with the concept of place value and counting by tens.

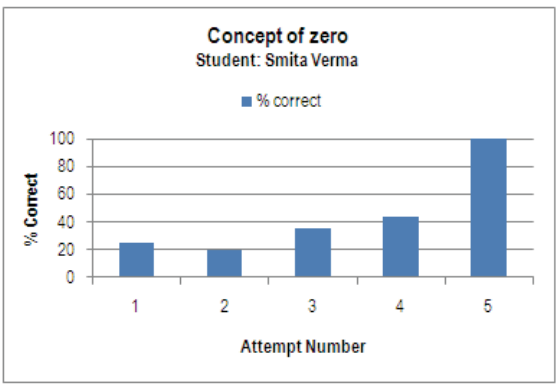


Sapna, a Class 5 student, was doing place value questions in Mindspark. She came to an abacus where she had to count the total number of beads. Here, she counted all the beads one-by-one – up to 72. In the next level, it was the same kind of question, but the visual would disappear quite quickly, so that kids are not able to count in ones. Sapna kept trying to count in ones and could not finish. So, when she got this type of question a third time, she started off – really fast and furiously – 'dus-bees-tees-chalis-ektaalis-bayalis-tetalis-chawalis-paentalis' ... all in one breath!! Then, she took one long breath and chose '84'! She had 'learnt' to count in tens-and-ones without 'instruction'.

Names of students have been changed to protect their identities.

Apart from observations like the above, data also gives clear evidence of learning. For instance, an analysis of the number of attempts a child had to make to 'understand' a concept gives an insightful view into their learning progression. In Mindspark, a concept is broken up into learning units. The topic Whole Number Concepts consists of 27 learning units. Data shows not only a difference between students (some complete the learning unit in one attempt while others take up to 7 attempts) but also that the performance of students improves from attempt to attempt.





Writing a number from its expanded form is important to understanding place value. Understanding the concept of zero is also a key learning. Here, Smita and Anand, students of Classes 4 and 5, respectively in the Mumbai trials, 'understood' the concepts (i.e. reached 100% correct level) only after sustained interventions of Mindspark. The improvements across attempts were visible for most students.

ATTITUDINAL CHANGES AND INCREASE IN CONFIDENCE

Students came to school to do Mindspark even on holidays!

The system's adaptive logic allows each child to work at her own pace. Its ability to 'find the child's level' ensures that even the weakest child has a *high success rate* (above 60%), which in turn has a positive impact on her confidence levels. To understand this, consider the case of a child who answers a few questions wrongly. The system immediately switches to easier questions, this continues till the system is asking questions the child is able to answer. This success rate boosts the child's confidence in Maths and reinforces her interest in the subject. This was visible during the Mumbai trials when students came for Mindspark classes on Saturday (a holiday), not just when the programme began, but even in the seventh and last week of the pilot. In settings where drop-out rate and absenteeism is extremely high, this speaks a lot about the potential of a system like this.

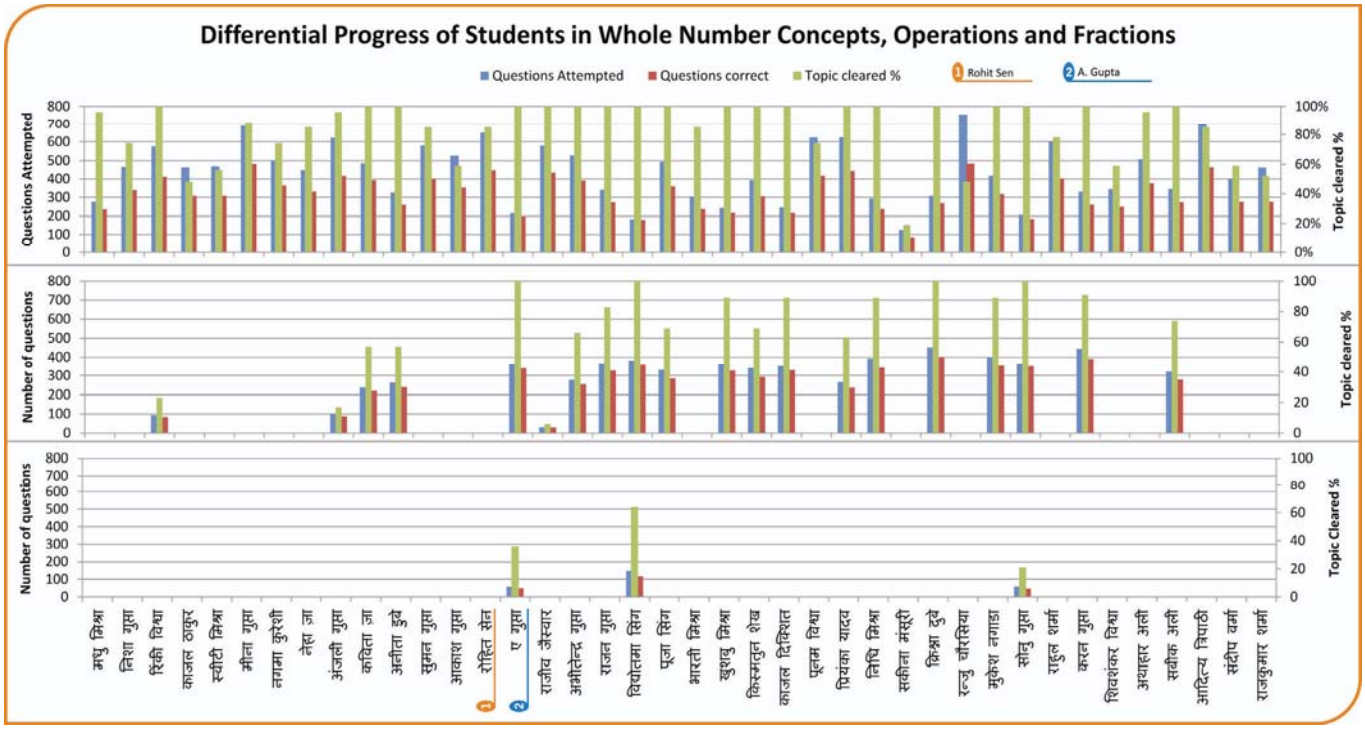
DETAILED SNAPSHOT OF LEARNING SHOWING DIFFERENT PACES

A personalised learning system like Mindspark generates rich data showing student progress. The data produced provides a detailed, quantitative snapshot of the learning process. Here are some samples available from one of the reports:

S. No.	Name	Class	Number of Sessions	Total Time (hr:min:sec)	Total Questions	% Correct	Topic-wise Progress*	Time per Question (s)	Read out Requests
1	**Rohit Sen**	4	17	08:42:23	668	68.86	WNC (85%), WNO (0%), FRAC (0%)	37.58	347
2	**A Gupta**	4	16	08:09:50	632	93.35	WNC (100%), WNO (100%), FRAC (36%)	38	20

**WNC – Whole Number Concepts; WNO – Whole Number Operations; FRAC – Fractions.*

The following graphs show the progress information for all the children of a class. The graph represents a topic which is a pre-requisite for the second topic. Hence, only students who complete the first topic (represented by the green bar reaching 100%) can start the second topic. Similarly, only those completing the second topic can start the third.



The graphs show the progress of students of the Mumbai trials on three different parameters -- the number of questions attempted (blue), the number of questions answered correctly (red) and the overall topic progress (green). Those who have completed Whole Number Concepts (achieved 100% topic progress) have moved to the Whole Number Operations topic (this is the second graph above) and those who have completed this too, have moved to the Fractions topic (the last graph).

The graphs clearly show that students who complete the most questions are *not* necessarily the ones who make the most 'progress'. Topic progress depends on both a high success rate and the number of questions answered. Detailed learning information like this can be extremely useful even years later, when – for example – a class 7 teacher may want to look back and check whether a particular student struggling with algebra simplifications developed pre-algebra skills well.

THE FUTURE POTENTIAL OF MINDSPARK

A system like Mindspark tries to capture information about student learning available in research and use it to help students learn. It also keeps collecting data on student learning. Thus, it is a system that is geared to improve and become much better as time passes.

Secondly, a system like Mindspark can work in multiple ways – as an 'assistant teacher' who gives the individual attention that a single teacher in a large class cannot; as a system that provides personalised activities to each child as per her ability; and as a feedback source for the teacher who wants to know how much the students have learnt.

Thirdly, contrary to fears of high cost, Mindspark can be a low cost solution once the hardware infrastructure is in place. We expect that teacher training and teacher support required will be high in the initial years, but will not be required as time passes. At this stage, the cost of Mindspark can probably go down to as low as Rs 50/- per child per month.

Most exciting, however, is the vision of the future. We anticipate that decades from now, students would spend about 50% of their school day on personalised, cognitive learning systems like Mindspark. *The remaining 50% will be spent with their peers under the guidance of one or two 'teachers', where they will learn teamwork, values, sharing and the important things no system can probably teach.*

FEEDBACK FROM STUDENTS, TEACHERS AND OBSERVERS

Student Feedback was obtained through individual and group discussions from students who had participated in the Mindspark trials.

- A few students shared that they found attending regular classes very boring as there were too many students and the teacher could not always clear their doubts, but with Mindspark they could attempt questions on their own and take as much time as they wanted.
- A class 3 student said that in her regular class she was always left behind the others and she really enjoyed Mindspark because she was never left behind anybody.
- A class 5 student shared that he never used to pay attention in class; but, due to Mindspark he had gained a lot of confidence in place value and in addition in which he was weak. Also, there was no fear of being scolded or being beaten up for not understanding something.

An EI facilitator looks on while a child answers a Mindspark question in Ratlam.

Teacher and Observer Feedback was systematically obtained in writing:

- A teacher from Mumbai mentioned that he had noticed changes in students' attitude towards learning and their ability to add and subtract.
- A Naandi Foundation representative, who was present throughout the pilot study, observed that she could actually see the students thinking, which is a rare sight in most programmes. She also expressed the opinion that the immediate feedback provided by Mindspark helps in keeping students engaged and making them want to perform better on the next question, unlike the exams that give out results after a month or so.
- McKinsey & Co. was an observer during the Mumbai Municipal School trials. The McKinsey representative said that the programme was very well-received and the children were very enthusiastic. He also observed that the programme seemed to have "helped the target group of students in seven weeks tremendously." His concerns were about infrastructure and cost if the programme was to be scaled.

RESPONSES TO COMMON OBJECTIONS

There are justifiably concerns and common questions raised about a new learning system like Mindspark. We discuss some of them here.

- ***Can technology really help students learn?*** This is a valid concern considering that so far e-learning has probably been more about promise and less about results. We see Mindspark to be an *educational* programme – built on educational research and data - which is *technology-assisted*. It should also be noted that Mindspark seeks to only complement and assist the teacher. In fact, we believe that an effective personalised learning programme will enrich a teacher and allow her to focus on activities and projects that she is not able to do today.
- ***Won't it be too expensive?*** There is a fear that technology-based learning programmes will be expensive and hence unaffordable. We believe that technology at scale is the best way to *reduce* costs. With a system like Mindspark – like typical software – costs fall with increasing volumes. A unique feature of Mindspark is that since it is based on student learning data, its effectiveness actually increases with increased volumes and usage. Hence, while there is a huge development effort involved, we believe this will be more than offset by the benefits it can afford to lakhs of children and more. Relevance and effectiveness make cost irrelevant.
- ***What about the teacher?*** A valid objection is that systems like Mindspark cannot succeed unless the teacher becomes a partner and sees them as useful. Our experience confirms the same, and we anticipate that the greatest investment in the early period will be on teacher training and teacher support.

  As it starts getting used effectively however, Mindspark will supplement and enhance what is taught in class, by removing misconceptions and giving students a chance to learn at their own pace. In fact, Mindspark will free teachers' time enough to allow them to focus on higher level activities that they are not currently able to do, but which will enhance students' understanding.

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ABOUT EI

This is a working paper on the potential of using Mindspark, a question-based adaptive learning programme, to help rural and municipal school children learn basic concepts. It summaries two interesting pilot studies conducted to track the learning progress in rural and municipal school students due to engagement with Mindspark. The results suggest that the personalised intervention provided by the software helps in improving learning and also in changing students' attitudes towards learning. Mindspark has the potential to make an enormous difference in the way students learn especially in municipal and rural school settings.

We are an educational research organization that focuses on learning research through assessments. EI has been started by a group of IIM Ahmedabad alumni with first-hand experience of setting up and running educational institutions. It has been formed with a mission to work towards qualitative improvement in India's educational system and our vision is "A world where children everywhere are 'Learning with Understanding'".

PROJECTS OF EI:

Andhra Pradesh Randomised Evaluation Study (2004 onwards): Done in partnership with Harvard University, Azim Premji Foundation, World Bank and the Government of Andhra Pradesh, this is a longitudinal study across 8-9 years and covers currently 100,000 elementary school kids and measures the impact of various inputs (e.g., block grants, additional teachers) with outcome-based teacher incentives.

Assessment of Student Learning in Sarva Shiksha Abhiyan – RGSM, Chhattisgarh (2008 onwards): The test was developed in Hindi and administered to approximately 3 lakh students in about 1900 schools in 16 districts in Chhattisgarh states. The tests have already been conducted for students of class 3 to 8 for Language and Maths and the report is in final stages.

Municipal School Benchmarking Study (2004-2007): Supported by ICICI Bank, this study assessed learning in 35,000 municipal school students from class 2, 4 and 6 across the 6 biggest towns in each of the states - Gujarat, Andhra Pradesh, Rajasthan, Chhattisgarh and Uttarakhand.

UNICEF Learning Assessment Study for Quality Education (2005-2006): assessed mathematics and language acquisition among primary school children in the UNICEF quality package schools in 13 states of India. The tests were standardised across 9 languages and involved very intricate development cycle involving language experts from all over India.

Teacher Needs Assessment (2008 onwards): is a census study that has been initiated by the Royal Education Council, Government of Bhutan. In this project all teachers of Bhutan are assessed for their general ability, competence in subject knowledge and pedagogical practices.

Student Learning Study (2008-2009): Supported by Google Inc., this study is currently ongoing and assesses student learning in 21 states of India. Nearly 190000 students in classes 4, 6 and 8 are tested for learning in Language and Maths in rural and urban govt. schools.

EI'S PRODUCTS AND LEARNING SOLUTIONS:

ASSET: is an objective-type, multiple-choice test for students of Classes 3 to 10. It is a scientifically designed, skill based assessment developed in India for Indian schools. It assesses students' level of proficiency in the skills and concepts underlying the school syllabus and provides them feedback about their strengths and weaknesses. Know more about ASSET at www.ei-india.com

Mindspark: is a computer based self-learning programme that helps the child improve her skills. It allows each student to follow a learning path that is based on her need. Mindspark is currently available for Maths for classes 1-10 in English version. Mindspark can be accessed at www.mindspark.in.

Rural Mindspark: Hindi version is currently available on demand for some Maths modules. Contact EI to know more about other language versions and modules.

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