23 Insights about Student Learning from an Adaptive Learning Math Program

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Introduction

Can we use computer technology to help our children learn better? On one hand, the way this technology has transformed our lives in every sector suggests that the answer is a clear 'yes'. Yet, in spite of a lot of investment over many years, the track record of computers in making a visible, positive impact on student learning – in India and internationally - has not been impressive. Many would say that the hype has been much bigger than actual outcomes.

We believe that the main reason for this has been that educational Information and Computer Technology (ICT) solutions have been too little 'educational' and too much 'ICT solutions'. We approached this problem from the education end – working for over 12 years on student learning (with no ICT offering in that period). For part of this period we ran a school while for another part we assessed the learning levels of lakhs of students across private and government schools testing for understanding and not mere recall of facts or procedures. Following the assessments, student interviews were conducted on important misconceptions that came out which told us why students were thinking in a particular way. Through workshops and diagnostic 'Teacher Sheets' we shared this feedback with teachers. But at a point, we realised that all the voluminous (and fascinating!) educational data we had could probably be used directly to create measurable learning improvement.

Why ICT is Critical – the Complexities of Learning

We now believe that the complexities of the process of student learning are such that we have to rely on computer technology if we really want every child to learn with understanding. The complexity comes in two ways: one, the process of learning new concepts is inherently complex and probably contains more stages and nuances than a person who has 'learnt' them realises. And two, each student's way of learning a concept, not to mention the pace, tends to be different. Today we can support this constructivist paradigm with hard, detailed data on the learning levels of thousands of children.

Underlying Principles

Mindspark is a computer-based adaptive learning system which primarily uses questions to help children learn. The questions are of 'finely-graded' meaning such that there are a very large number of questions of gradually increasing levels of difficulty. Questions are specially designed to test understanding and to help students clear misconceptions. (Increasingly, Mindspark student usage data is itself throwing up prevalent misconceptions.) There is very little emphasis on instruction due to the belief that students learn when they have to think – either to answer a question, or

do an activity on the computer. This is also done as we see Mindspark as complementary to the teacher and in fact an unobtrusive professional development tool for the teacher himself.

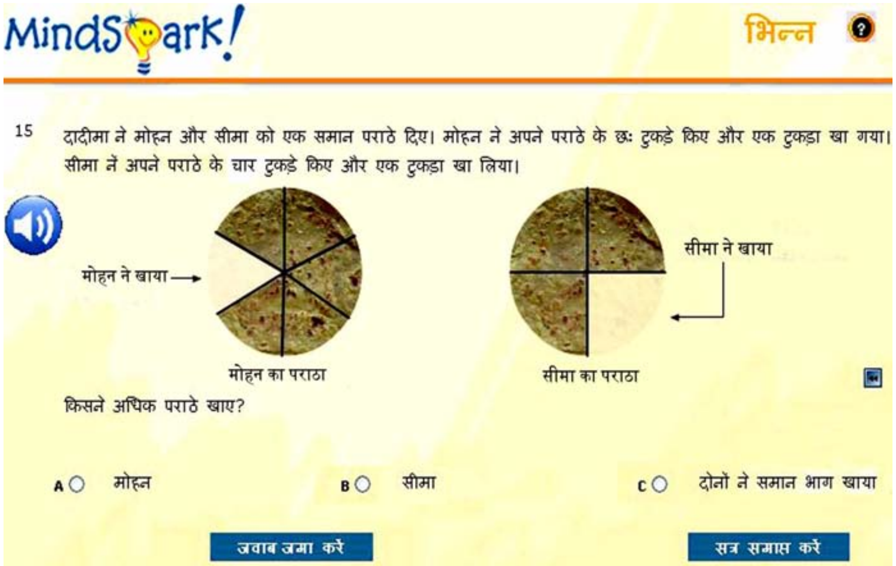


Fig 1: A question-based adaptive learning software gets students to progressively answer questions of increasing complexity, allowing them to learn at their own pace and get basic concepts cleared before attempting higher ones.

When a student answers a question incorrectly, she may be provided a simple or detailed explanation, or be redirected to questions that strengthen the basic understanding. These decisions are taken by an adaptive logic which is expected to get better and better with increased student usage. The system is available in private and government school editions and in both, it is used in school with usage time-tabled into the schedule. It thus aims to use not just the interactivity of the computer, but its intelligence; and mimics the diagnostic capabilities of a good teacher.

The Benefits

There are many benefits of such an ICT-based adaptive learning system. To quote one, when students work one-on-one on problems, their attitude towards Math seems to change – they realise that when they engage with a problem, it is not so difficult to solve! (Perhaps a philosophy that goes beyond Math) Here, however, we shall focus on two important benefits: insights into learning for educationists and teachers and personalised learning that seems to result in learning improvements.

Insights into Learning for Educationists and Teachers

A New Look at Learning: We are finding that the data from a program like Mindspark may allow such questions to be answered as could not even have been seriously asked before (for example, how much time does it actually take class 4 children to learn fractions?) The way we look at learning, as something we can perceive, but not get a very clear handle of, may change a fair bit with much more detailed information available on learning. Needless to say, 'detailed' does not mean accurate, so such data will need to be subjected to critical and sceptical scrutiny, but statements like this do seem justified from the data: “Ramesh has progressed 12.7% in the topic as compared to 71.3% average progress of the class in the same period of time.” Individual student interactions convince us that these data do capture learning reasonably accurately and provide pointers to teachers on specific gaps that can now be addressed.

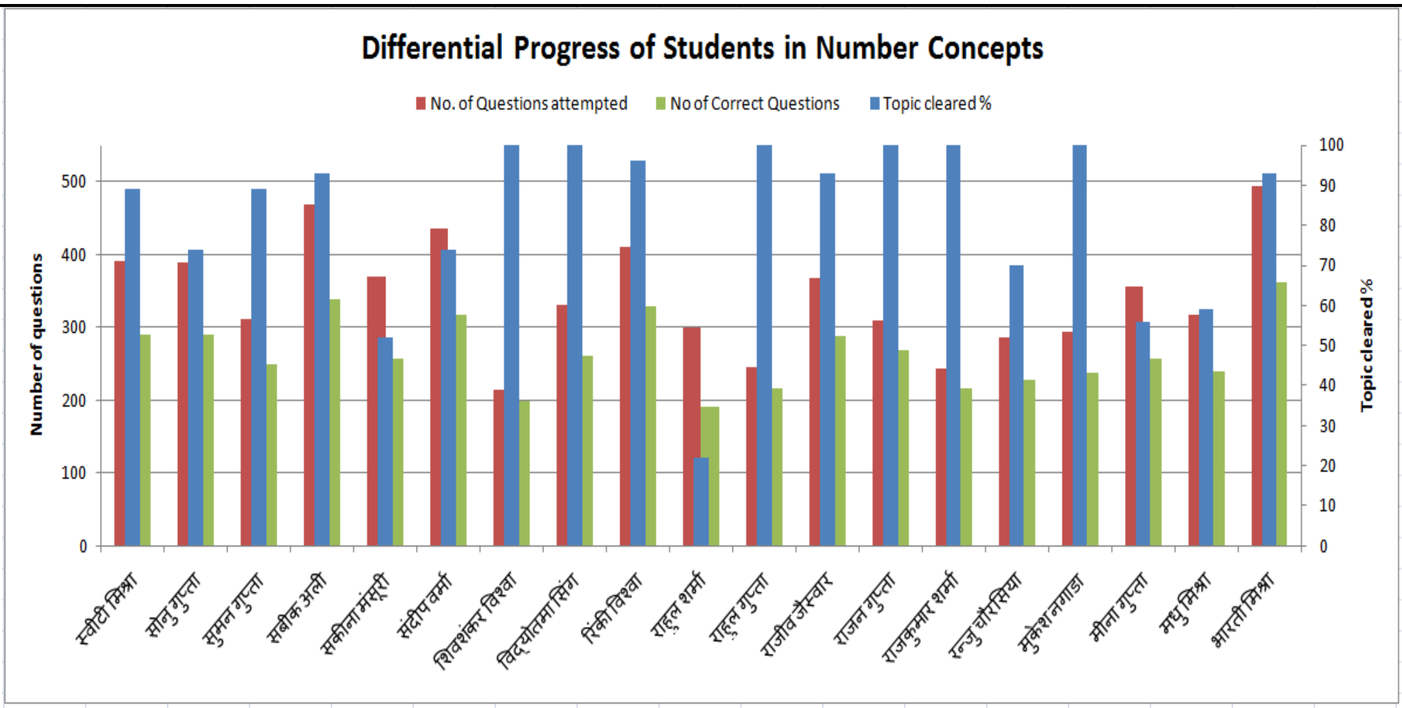


Fig 2: Though these students spent the same amount of time, the number of questions done, accuracy and overall progress vary a lot.

- *This is not a statement against whole-class or group learning which should happen in the other Math-learning time.*
- *Throughout this article, names have been changed to protect the privacy of students.*

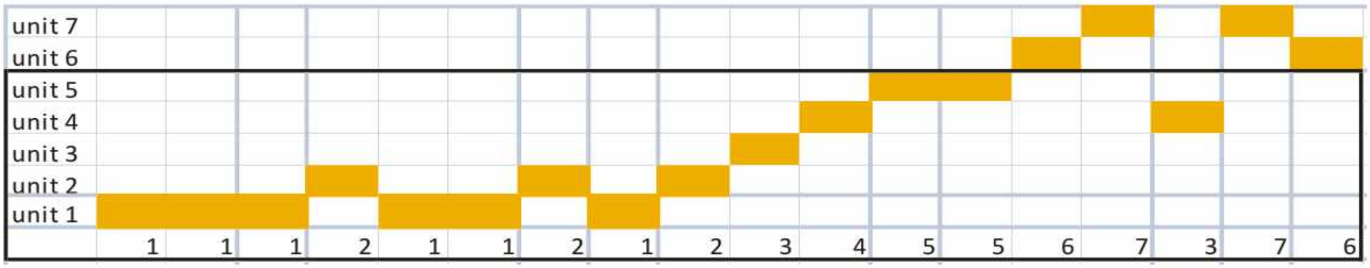


Fig 3: The progress graph of an individual student on a single topic.
The black border represents the topics corresponding to the current class.

Sr. No.	Cluster Code	Flow No	Attempt Type	Cluster Attempt No	Result	No. of ques attempted	% correct	Last Modified
Topic Attempt No: 1	(TT Attempt ID:36039)							
1	FRA003	3	Normal	1	FAILURE	17	52.94	2009-11-04 11:35:20
2	FRA003	3	Remedial	2	FAILURE	23	60.87	2009-11-06 13:09:52
3	FRA002	2	Normal	1	FAILURE	3	0	2009-11-06 13:11:02
4	FRA002	2	Remedial	2	FAILURE	3	0	2009-11-06 13:11:33
5	FRA001	1	Normal	1	FAILURE	19	73.68	2009-11-06 13:25:47
6	FRA001	1	Remedial	2	FAILURE	22	59.09	2009-11-16 12:53:12
7	FRA001	1	Normal	3	SUCCESS	18	77.78	2009-11-16 13:06:17
8	FRA002	2	Normal	3	FAILURE	5	20	2009-11-16 13:08:32
9	FRA001	1	Normal	4	SUCCESS	14	100	2009-11-16 13:17:25
10	FRA002	2	Normal	4	FAILURE	18	72.22	2009-11-23 11:11:30
11	FRA001	1	Normal	5	SUCCESS	16	87.5	2009-11-23 11:20:00
12	FRA002	2	Normal	5	SUCCESS	17	76.47	2009-11-23 11:30:19

fig 4: A table with more detailed information on a different student's progress

Figures 2 to 4 show some of the detailed information available about learning from such systems. Note that each aspect of these graphs and tables can be drilled into till we get to the level of an individual student, an individual concept, or even an individual question. Since overall progress decisions are based on a large number of questions, they seem to correctly represent learning – as can be verified by teachers and researchers talking to the concerned students. The net insight: we need to go really deep into trying to understand how learning takes place, if we have to really improve student learning.

The Individualised Nature of Student Learning:

Preliminary data suggests that both learning paths and 'strengths' and 'weaknesses' tend to be fairly individualized. When we looked at the lists of better-performing students in different topics, we found that there was less overlap than we would expect from labels like 'strong in Math' or 'weak in Math'. Similarly individual misconceptions and the time taken to grasp specific sub-concepts seemed quite unique for each child.

In some cases (and we suspect they will be more frequent) students designated as 'slow learners' were found to be having difficulty in specific basic concepts – when these were cleared, these students performed significantly above the class average.

While a number of misconceptions common across students were identified, it was also found that many students had misconceptions and difficulties that seemed unique to the particular student (for example a student who seemed to be mixing up between ¼ and ½ consistently over a certain period of time.)

Specific Information for Teachers: we found that by and large, when provided with data which was actionable, teachers took interest and tried acting upon it. Teachers themselves sought certain reports – and these have turned out to be the most useful reports across all schools. Teachers say that information about concepts not learnt by all or even a sub-group of students is extremely useful for them and allows them to immediately address the problem. There are occasionally cases where the student has not learnt in spite of various system strategies. Such cases are referred by the system to the teacher – something teachers have appreciated.

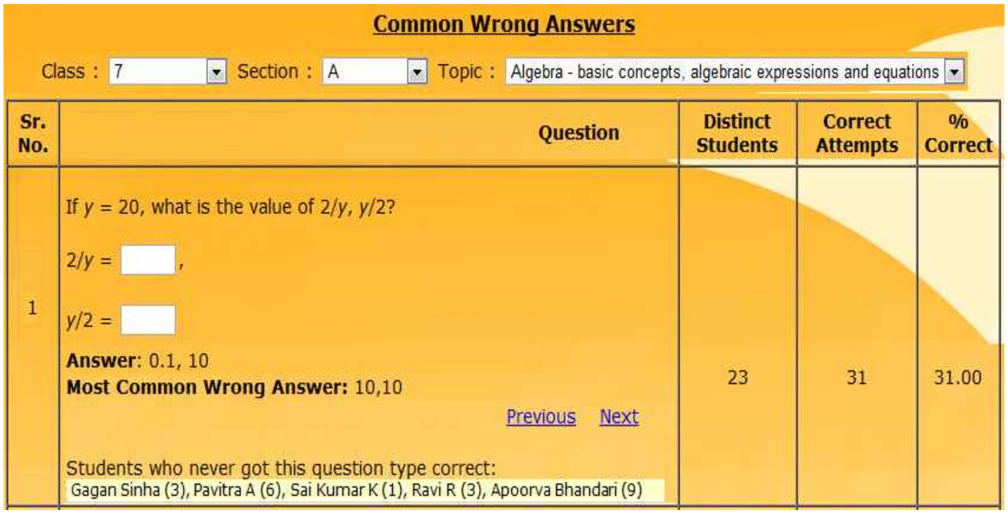


Fig 5: This report was created iteratively based on a request from some teachers. It lists out the 'common errors' in class or section. A question type would have different questions and a teacher can see all the different questions and the errors children made. The names and number of attempts of students who never got the question type correct (shown in yellow highlight) – became a simple action point for teachers.

Subject-specific Insights: needless to say, there are many specific errors that are detected from the data. Many are known from research, but teachers find this easier to relate to and accept. Some examples from Algebra, class 6 (which, incidentally, tallies with research in this area):

See, for example, Warren, 2003.

- *5 less than t' is considered 5 - t.*
- *20 = 5x4 is considered wrong by many students*
- *Difficulty representing expressions like 'half of 8 less than n' algebraically*
- *Difficulty with questions involving minus signs like the value of -5t or -t + 5 when t equals 2*
- *Confusion between terms like k + 3, 3k, k^3, etc.*

Personalised Learning that seems to lead to Learning Improvements

Programs like this try to tackle the challenging question 'what is needed to help children learn a new concept well?' As most teachers know, the answer seems to be different for different topics, different students and even at different times!

At times, students seem to learn through repeated exposure that increases the familiarity of a concept. At other times, identifying a key misconception and providing more exposure to that concept seems to aid learning. And sometimes, a difficult or non-intuitive concept has to be carefully explained.

We have interesting examples where all these three seem to work. Three cases, one of each type, are shared below:

Case 1: Counting in 10s:

In a municipal school which was using Mindspark, students of class 5 were struggling with class 1 and 2 concepts (unfortunately, a common situation) Sapna, a Class 5 student, was doing place value questions in Mindspark. She reached a question in which she had to count the total number of beads. She counted all the beads one-by-one – up to 84, in that case!

But after a few such questions, in the next level, the visual would disappear quite quickly, not giving her time to count in ones. On the third or fourth such question, 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 wrote '45' (the correct answer) in the blank! The observers burst out laughing - she had 'learnt' to count in tens-and-ones without 'instruction'.

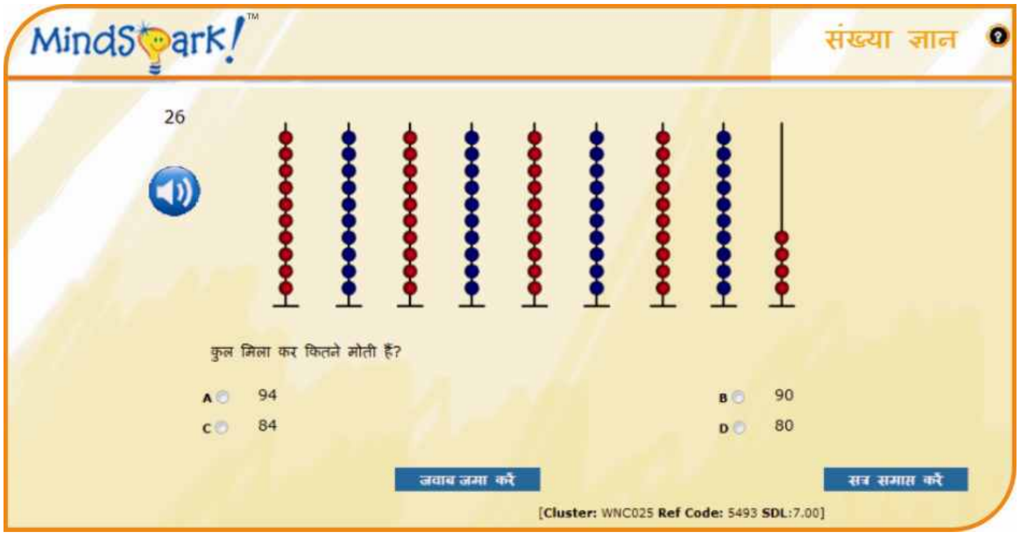
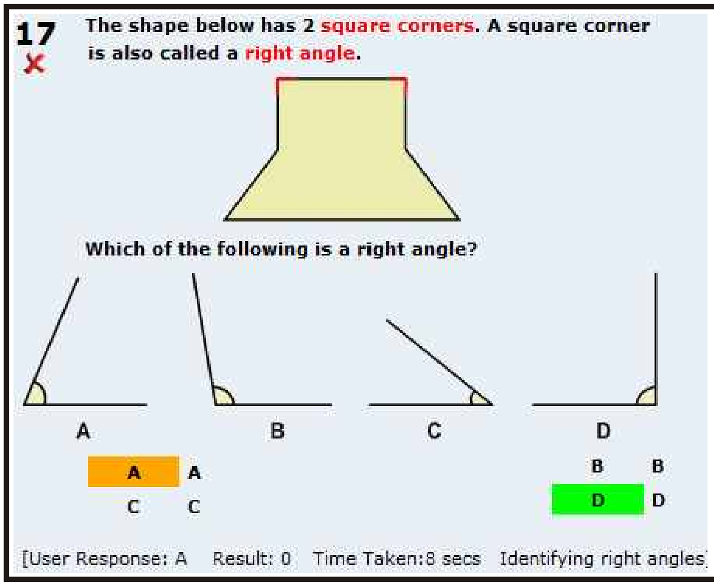


Fig 6: Simple animations – here, a set of beads that need to be counted before they disappear – helped a child understand counting by tens.



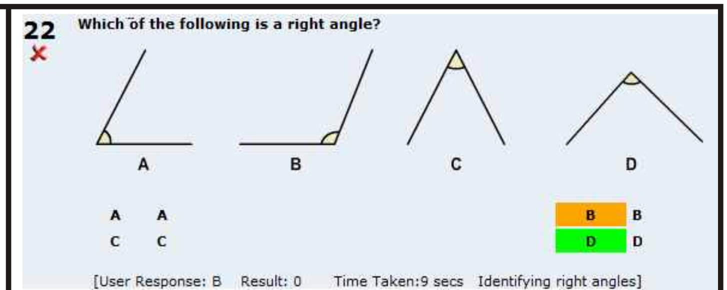
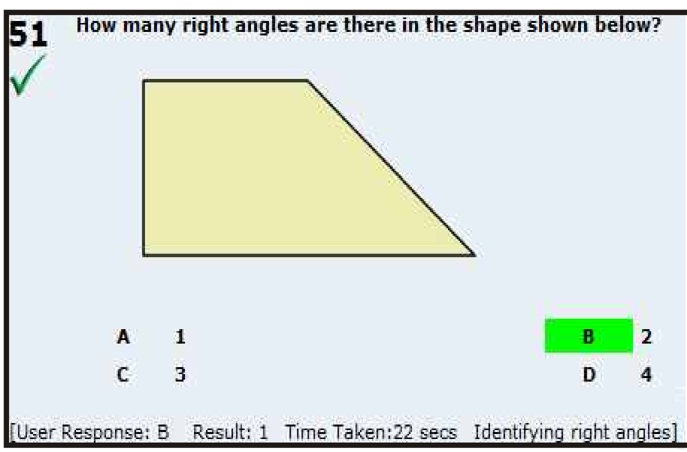


Fig 7 (left): recognising a right angle in standard orientation
Fig 8 (top): recognising a right angle in non-standard orientation

The student was unable to identify a right angle visually in the beginning either in the standard or non-standard orientation. After a number of questions that both challenge and explain this concept in different ways, the child is clearly able to answer these questions correctly.



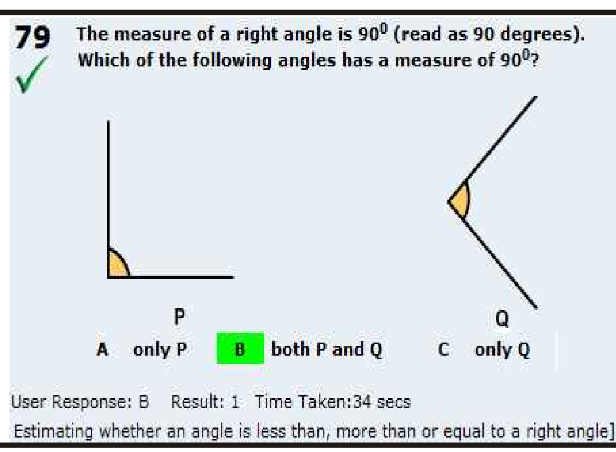


Fig 9 (far left) and Fig 10: more questions on right angles

Case 2: Understanding Angles:

One of the most interesting analyses is the study of a student's 'trail' – the questions attempted by him or her one by one (sometimes over weeks). Here are some questions in a trail of questions on 'angles' attempted by a class 5 child. The questions were done over a week and the sequence numbers are shown. Though only 4 questions are shown here, the inferences are based on analysing the student's responses to many more questions and the pattern is clear.

3: Operations with Negative Numbers:

In some cases, students learn when they are given conceptual reinforcement that addresses a doubt or a problem they have, or gives them an appropriate analogy that helps learning take place. This applies to doubts related to negative numbers, the concept of variables in algebra, etc.

In all these cases, more studies need to be conducted to confirm that the learning is really robust. However, early indications were clearly positive, and suggest that some of these strategies were working to help children learn key concepts they were previously struggling with.

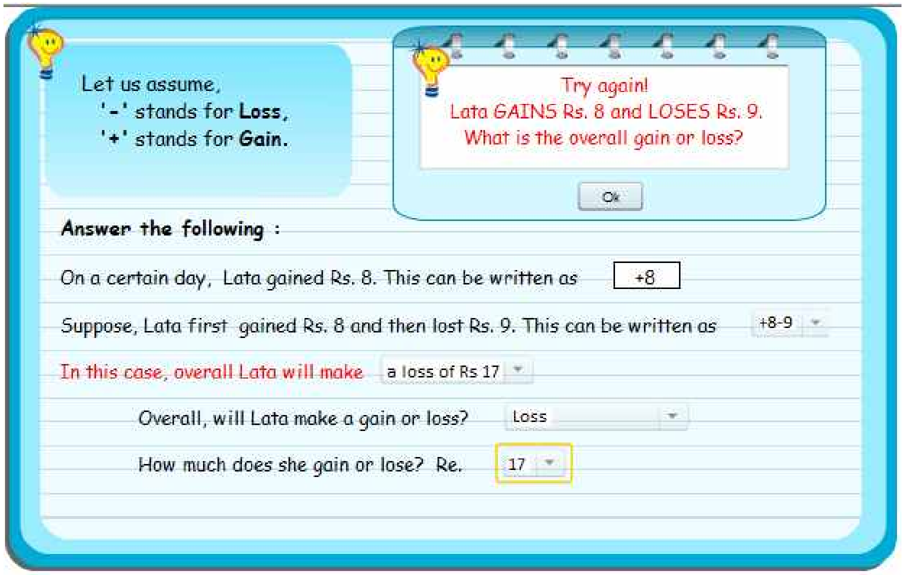


Fig 10: The above is an interactive remedial item that is only given to students who are not able to handle integer operations. By giving analogies and leading the child through a series of exercises, some children were found to understand the concept (rather than simply remember and apply a rule to handle problems.)

The Long Term Vision

Some people fear that the use of computers in instruction is undesirable as it ignores the human and relationships aspects of learning. There is also a fear that such technologies may further weaken the role of the teacher. Doubts are expressed whether students can really learn through questions.

Though it would not be possible to discuss all these objections in detail, we believe that in the long term, computer learning programs like these will be an important part of education, which will strengthen, not weaken the teacher. The teacher will continue to provide instruction, inspiration, challenge and guidance; the computer will provide individualised practice, remedial, challenge, clearing of conceptual doubts, and to the teacher – pointers on where she should focus. This freeing of the teacher's time, we believe, will allow her to spend more time on many things that are desirable but get left out today – development of social and team skills, project work, real-life activities and the ability to focus more on individual children and their specific needs.

References

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5. Kannan, KanthiMathi and Shukla, Anar. 'Breathing Easy?' Science Reporter; January 2008; Vol. 45; pp. 23-8.

6. Warren, Elizabeth. 'The Role of Arithmetic Structure in the Transition from Arithmetic to Algebra;' Mathematics Education Research Journal, 2003, Vol. 15, No. 2, pp. 122-37.
7. The article 'The Potential of Assessment in Science' (2009) by Agnihotri et al describes this process and also some interesting misconceptions found among students.
8. Many researches on student learning confirm this. Seemingly basic concepts like place value, the notion of respiration or the measurement of learning can be surprisingly difficult to really grasp. See, Kannan and Shukla (2008) and Kamii (2006).

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Numbers

All numbers are created equal
Yet some are more prime
But then why some are real
And others are truly imaginary?

All numbers are created equal
Yet all numbers are complex.
But then why some numbers
Are more rational than others?

All numbers are created equal
And many numbers are integral
But then why some are positive
And others are negative?

All numbers are created equal
And many numbers have values
But then why there is a number
That's zero like an empty tumbler?

Are there equal numbers?
Or is it only in my slumber
That I see transcendental numbers
And the eternal infinity?

- By Krishnan Balasubramanian