Manipulatives are not Magic: Ground Realities in the Mathematics Classroom

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For decades, numerous initiatives have been trying to transform mathematics education through the "math lab" approach. Is this a worthy quest? How is this transformation measured? And why is it that little turnaround has been reported?

When the geologist Jean de Heinzelin was slicing out sections of rock from the shore of Lake Edward in Congo in the 1950s, he was not surprised to come across the occasional human bone or human-made object. After all, the region—called Ishango—was known to have been occupied by prehistoric human settlements. What he definitely did not expect was to unearth the (possibly) earliest known example of a mathematical instrument.

We still don't know for sure what the mysterious patterns on the "Ishango bone" signify, but some experts are convinced they are evidence that our ancestors from 20,000 years ago were already playing with numbers, arithmetic operations, progressions and prime numbers. Whatever the actual story of the Ishango Bone, it is a striking example of how physical objects can profoundly shape our early understanding of mathematics.

The latest ASER report (2024), a nationwide rural household survey that reached nearly 6.5 lakh children across 605 rural districts in India, once again highlighted that there continues to be grave problems with how mathematics is being taught and assessed at our schools. Less than 50% of Class 8 students were able to do basic arithmetic. This is concerning because it is established that proficiency in mathematics is indicative of children's later life success in employment as well as in independent living.

Usha Menon, educationist and founder of Jodo Gyan, wrote in an article: "Children today… need not become calculators like some people had to in the nineteenth century. They need to become people who can pose new problems to solve in order to face today's challenges, whether of climate change or of increasing inequalities. They need to learn to think quantitatively and not just numerically, to think relationally and not just procedurally."

Getting under the skin of mathematics

In recognition of this, governments, NGOs, schools and teachers have led various initiatives over the past decades to improve the situation. One of the strategies deployed to achieve our foundational numeracy goals has been the inclusion of Teaching Learning Material (TLM) such as manipulatives in the classroom. Examples of math manipulatives or *mat(h)erial*—as they are known in Azim Premji University's Math Space—are many. There is the ganitmala, a chain of beads used to learn whole numbers; Dienes blocks or Flats-Longs-Units used for basic arithmetic operations; and arrow cards used to understand place value.

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When there is physical material in the classroom, children are inclined to pick them up and play with them. In doing so, such interactions can help children develop intuitions about number and mathematical relationships. Garima Bhatt, who is a mathematics teacher at the Azim Premji School in Uttarakhand, sometimes leaves the material with her students in class. "At least in the primary grades, the joy of materials should not be taken away and students should not depend on the teacher to learn everything," she said. Often, she enters class only to be accosted by eager children who have been playing games with the objects. "I realised that the children had looked at the instructions at the back of the box or interpreted the rules through the pictures."

"You really don't have to teach them," reaffirmed Swati Sircar, who co-created and runs the university's Math Space. "Once we left a 2-metre scale fixed to the ground of a classroom in Uttarkashi," she recalled. When they returned, they found children stretched out on the ground excitedly measuring their heights. "The children have access to the objects even when mathematics class is not happening. And they learn even faster when there are older kids in the room." She remembered a Montessori school teacher's amazement. "Our kids have been adding and subtracting their parents' phone numbers!" the teacher raved to her, marvelling at their comfort with ten-digit numbers.

Though it is very likely that manipulatives were being used in mathematical learning in pre-colonial times (using pebbles, seeds, shells, sticks, etc.), the teaching of mathematics became largely restricted to the blackboard and textbooks in the past century. The influence of the educationist Maria Montessori resulted in Montessori schools cropping up around the country in the 1900s. These schools used manipulatives to teach math and other basic skills in early education, but they were the exceptions. A slew of programmes by the government in the later years of the 20th century, such as the District Primary Education Programme (DPEP), reintroduced the idea of teaching math in more tactile ways. This has been reiterated with every new report about primary education, notably the National Curriculum Framework 2022 and the National Education Policy. Consequently, more and more schools in India have installed math labs in the hope that this will tackle the prevalent attitude of 'math phobia' among students.

It doesn't always work

More than 75% of the schools which participated in the ASER survey had received TLM and/or funds to make or purchase TLM for foundational literacy and numeracy. While these are encouraging signs, those who work on the ground observe that merely having a math lab in the school will not do. It all comes down to how they end up being used. Can pupils use a particular manipulative in such a way that it connects with their existing knowledge, and hence is meaningful to them? Is the manipulative used in such a way that it requires reflection or thought on the part of students?

"The main thing is that all students in a class should have access to some concrete material, so that it's not just the teacher demonstrating," stressed Swati. Considering the high strength of a typical Indian classroom, it is not realistic to aim for one set for each student, but according to her, 7 to 8 sets for a class of 30 is adequate. While this may be achievable by the more elite private schools, for the majority of primary schools in India, even this ends up being a costly affair.

The problem is exacerbated because six- to ten-year-olds aren't exactly the gentlest of handlers. "Some students end up breaking things while playing with them. At times, they take the small cards or tokens home without permission," said Garima. Wary of such instances, many schools end up limiting access of students to math labs, sometimes to such an extent that Swati dubs them "math temples". "The students are taken there in a line, not allowed to touch anything, they just do one round of *darshan* and then go back to class," she lamented.

A thrifty way out of this obstacle is to use material that is easily available, cheap, and convenient to fix or repair when broken. Making and distributing low-cost or zero-cost math kits has been one of the main activities of Swati's Math Space during its 12-year history. Students from the university, predominantly the BSc-BEd pursuers, are signed up to conceptualise and create mat(h)erial using recycled material sourced from the campus ecosystem such as cardboard, broomsticks, discarded packaging material, etc. "The moment material goes to kids, you should expect wear and tear, some will get lost, etc. Instead of fretting over that, you can just replace them!" said Swati.

Using locally sourced material has another advantage. Studies show that familiarity with a resource helps in learning. This familiarity can be achieved by using material that students come across in their context. For example, a Hungarian classroom may use chestnuts to learn counting, but chestnuts may be completely unfamiliar to a student in a town in Telangana. The young student may end up distracted by this strange object and unable to relate to the teacher's storytelling. Groundnuts may be a better example.

"If a learner is very conscious of various attributes of the resource it is unlikely to facilitate its use as a representation of a specific mathematical structure," wrote researcher Jenni Back in an article published by the University of Cambridge. "One resource that I frequently use in work on geometry is loops of string and I find that unless I let learners of any age have a chance to play freely with the string for a while before setting a mathematical task, they will be distracted by their desire to play and explore various properties of the loop of string."

Right across the corner

An alternative to a math lab is a "math corner"—an interactive learning space within the classroom itself. "See, mathematics in the primary stage doesn't need electrical connections, water inlet and outlet, and any fancy stuff," pointed out Swati. "You really don't need to take kids to the lab every math period. The material can come to the child, instead." In the math corner model, the material is kept in closer and more constant contact with the students. This alternative is also suitable for resource- and space-limited settings.

Shivasharanappa, who teaches math at the Azim Premji School in Kalaburgi, mentioned that his students lose 8 to 10 minutes in transit to and from their math lab which is located on a different floor of the school. Garima's classroom, on the other hand, uses the math corner model, and hence her students can save this precious time.

Sometimes, Garima feels that a dedicated room for the math lab would make her students take the activities more seriously and keep the manipulatives safe. Moreover, "the place will have its own vibe, like the school library or science lab." That said, Garima realises that this comes with a risk. "It should not be the case that the material is kept protected, but out of reach of the children."

These days, the concept of the math lab has become quite popular, even fashionable. It was not so in the 1990s, when SN Gananath started Suvidya Education Resource Centre in Bengaluru. On the surface, this is a pleasant trend, but Gananath cautions that actual impact can only come if there is a constant and continuous engagement with teachers—preferably face-to-face, but if not, at least online. He noticed that when his organisation was invited to schools to deliver one-off workshops, the response was mixed. "They will all clap and everyone is happy, but we need more. It can take 3 to 4 years for teachers to change their views and develop confidence in the approach," he stated.

According to Gananath, for the math lab approach to be effective, a fundamental paradigm shift in the user mindset is essential. What he means by this is that most students, teachers and teacher-trainers have internalised the belief that mathematics is about procedures and computation. "It's not that they are lazy. They are not aware of the philosophy of why mathematics is taught in schools, so it is difficult for them to appreciate, accept and implement new ideas."

When sustained engagement happens, the results are tremendous. Gananath fondly remembered teachers from rural Karnataka who came for Suvidya's workshops thirty years ago, took the message to other districts, and still practise what they learnt then. "One teacher would travel from Kolar to Bengaluru for monthly workshops three whole years. She had actually been appointed as an English teacher but after this, she requested the Principal to change her subject to mathematics. Her fear of math disappeared and she started teaching it!"

Educationists and primary school math teachers seem to largely agree on one thing: manipulatives *do* work in stimulating curiosity, exploration, and observation among young learners. However, for this to happen, teachers need to play first, reminded Sneha Titus, editor of At Right Angles and co-creator of Math Space. "When the teacher seizes learning opportunities and teaching moments from this confident yet playful approach, it builds mathematical skills of documentation, reasoning, conjecture, argument—all of which lead to proof."

This is when the "magic" happens.

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