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Science Museums: Improving Science Education

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Across the world, it is acknowledged that quality science education is critical to building a dynamic workforce and a national population with the tools to evaluate and embrace progress. At the same time, there are not nearly enough teachers trained in science content, and even less who can teach these subjects using the most successful methods: hands-on and inquiry-based.

There are a lot of responses to these problems, and they all count. But together, they are not enough:

1) Formal university teacher accreditation programs are key, but their graduation rates are not large enough to yield large scale improvements in science teaching.

2) Informal science media, including television and web-sites like www.Thinkfinity.org for teachers and students, are valuable for their broad reach, but cannot replace formal education.

3) Likewise, content in periodicals such as Sanctuary-Asia kids science activities running in the comics sections of many Indian newspapers or shortcutscomic.com in U.S. newspapers are a powerful launchpad for interest in the natural sciences, but cannot replace classroom work.

More resources are needed to make real-time change in the quality of science education. And science museums are positioned to play key roles. Science museums are located throughout the nation in both rural and urban areas, and they have developed outreach programs beyond their buildings. They are full of science-educated staff and exhibits. And they have equipment appropriate to teaching about science and math. Many are experienced in working with school classes in their museums. Some also are experienced in working with classes in school settings. A few excel in training teachers.

In this article we will look at proven methods for science museums working with teachers and their classes in the United States and India.

In the United States we'll use the model of the New York Hall of Science where early work with teachers and students revealed several key issues:

1) More than 80% of elementary schools in New York City have teachers assigned to teach science without ever having taken a science course in college or received in-service (professional – post university) training.

2) These teachers and even some with science education backgrounds are uncomfortable teaching science subjects, communicate this discomfort to their students, and tend to teach by rote from science textbooks using the teacher answer sheet to determine correct outcomes.

3) When scientists/educators or science museum staff present science in the classroom or at the museum, both teachers and students rate the programs very highly...BUT the success of these "specialist science presenters" is seen by teachers and students as further proof that science is not something that they can really master. It is in the purview of specialists.

As a result, to reach the goal of increasing the quality of science education in New York City, the nation's largest school district, the Hall set these key objectives:

1) Every education program includes teacher professional development and empowerment – museum staff are tasked to teach, mentor and coach teachers. They do not replace them.

2) School administrators and educators are involved in program planning – museum staff seek to understand curriculum requirements, testing demands, limited facilities and equipment, schedule constraints, and special needs that school-based professionals understand deeply.

3) School administrators, educators and students are involved in evaluation.

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4) Wherever possible, the school's own systems are integrated into museum programs: test preparation, school-day schedules, teacher professional development, union and school administration requirements and budgets.

Using Museum-owned Equipment to Train and Empower Teachers

STARLAB™ projector training for teachers in professional development at the New York Hall of Science. Frank Signorello, instructing. (Photo credit: New York Hall of Science)

The best science educators know the content appropriate to their grade level(s) and a diverse set of methods to ensure teaching across many learning styles and life experiences that students bring into the classroom. The best science educators are confident in their knowledge of content and methods, and that confidence is also projected to their students who see them as able to teach science well.

Because many teachers do not have the resources necessary to teach beyond textbooks, and because textbooks have a tendency to encourage rote learning, one of the first programs undertaken sought a model for providing teachers with content, methods and equipment for use in their classrooms. The model was the STARLAB™ training and rental program, Many Indian science museums also own portable planetariums with STARLAB™projectors.

Teachers engaged in 20-30 hours of training in astronomy, cosmology and traditional constellation mythsrelated to the New York State mandated science curricula across a number of grade levels. They also learned proven hands-on and inquiry based methods for working with STARLAB™ and developed their own lesson plans. At the end of their training they received a week's free STARLAB™ portable planetarium loan for use in their school building and they were certified to rent additional weeks of STARLAB™ in their school.

A typical STARLAB™ week led by a STARLAB™ certified science teacher included a science curriculum unit with their own class and others in the same grade, and a parent night where both the trained teacher and students led STARLAB™ presentations in astronomy, cosmology or mythology.

Training on STARLAB™ portable planetarium set-up. (Photo credit: New York Hall of Science)

Evaluation demonstrated that in both New York City and science museums replicating this model in rural areas, trained teachers taught effectively using STARLAB™, they increased the use of hands-on methods in other aspects of their teaching, their students and others in the school saw them as able science teachers, and parents who attended STARLAB™ nights had more positive attitudes toward science education in their schools and their own child's ability to learn science.

The science museum as a part of education infrastructure supplying well-maintained, specialized equipment, and content and methods training to teachers on a consistent and ongoing basis is a powerful vehicle for increasing the quality of science education. In addition, if equipment can be rented at a fee equal to the nominal cost of maintenance, shipping and replacement, the museum program can be self-sustaining.

This model has been replicated in New York with a Microbiology Program: video-microscope (for all class teaching), field microscopes, organisms and culturing supplies for hands-on teaching. Abiotechnology- and a forensic-science based information technology program using a computer-mediated teacher/student software interface has also been produced and evaluated.

Using Teacher Training and Classroom Lesson Modeling to Improve Science Education

Teachers learn content & methods at the New York Hall of Science. (Photo credit: New York Hall of Science)

Another effective model for increasing the quality of science teaching involves work at the museum and in the classroom. In New York we had two district practices upon which to base training:

1) Required Annual Professional Development Days: Students are released from school and teachers choose from a catalogue of training offerings across the city including those of the science museum.

2) State Required periodic Professional Development courses: 25-30 hourcourses with or without equipment followed by classroom lesson modeling. These courses were designed to yield not only higher quality science teaching in both content and methods, but also professional credit that teachers need to maintain their teaching certification and receive higher salaries and/or positions as their careers progress.

As in the STARLAB™ model, training using museum staff (and, in later years, master teachers from earlier courses) took place in the museum. And as in the proven STARLAB™ model, training included both content correlated to the curricular requirements in each grade and also inquiry-based and hands-on methods for teaching this content. An exchange of lesson models developed by the teachers in training resulted. Ultimately this exchange was expanded with a website for uploading and downloading shared lesson plans, tips, questions and evaluation models produced by trained teachers.

To ensure successful cross-over from the well-supported museum training environment to the classroom, lessons were developed that could be co-taught by the trained teacher and museum staff in each teacher's classroom. Teachers often scheduled these classroom lesson modeling sessions in classes with particularly difficult demands….students speaking English as a second language, students with physical or mental handicaps that challenged hands-on learning, behavior issues, or students with very uneven learning patterns who were on grade level in some subjects and behind in others.

Modeling the use of hands-on and inquiry-based methods as a way for each student to find their own place vis a vis science content in these challenging classes was electrifying for both students and their teachers. Teachers became "stars" to students, and students became "successful" in the eyes of their teachers. Everyone was better positioned not only to learn science, but also to work with each other across all subjects.

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Highest Impact Correlates with Greatest Contact Hours

Outreach lesson modeling in the classroom (Photo credit: New York Hall of Science)

The two training models above have the advantage of reaching and changing the teaching content and habits of many teachers at a modest cost. The New York Hall of Science, for instance, was able to train 4,500 teachers per year using the per session rate that most schools have allotted in their budgets for teacher professional development. For these reasons alone, programs like the models above will likely dominate museum intervention in science education in the United States.

However, to actually change science education to the point where teachers routinely teach science more effectively, and, as a result, student test scores are higher, requires a more systematic supply of resources to teachers.

Three elements appear to be key:

1) Access to professional development on proven content and methods related to required curricula
2) Access to well-maintained equipment, including at least some basic equipment in a school lab
3) Ongoing access to an experienced science education "coach" who can help troubleshoot scheduling, content or methods problems, offer alternative lesson plans, encourage science teachers to take the ext step and serve as in-school advocates for quality science teaching -- especially when time or space resources beyond the usual schedule are required.

An ongoing model in New York uses a 3-year program to yield long-term, higher quality science education in a school building.

1) Year One includes:
   a. Goal setting with the principal and involved teachers
   b. Purchasing and setting up a basic lab (based on school budget realities)
   c. Initial teacher training
   d. Trained teachers working with their students
   e. Science museum-provided science education coach one day/week
   f. Teacher E-mail access to science coach

2) Year Two includes:
   a. Evaluating goals met & missed in year 1, and setting year 2 remedial and more advanced goals
   b. Introducing challenge-based learning (experiments designed by students)
   c. Introducing interdisciplinary projects (with social studies, technology, art, etc)
   d. Preparing students for exams
   e. Trained teachers working with their students
   f Science museum - provided science coach one day/week or every other week
   g. Teacher E-mail access to science coach

3) Year Three includes:
   a. Evaluating goals met & missed in year 2, and setting year 3 remedial and more advanced goals
   b. More consistent involvement of grades below and above target grades
   c. With teachers, identify and train student labtech volunteers to organize and clean labs allowing for higher volume use
   d. Trained teachers working with their students
   e. Science museum-provided science coach one

day every other week

f. Teacher e-mail access to science coach
g. Encourage communications between involved teachers
h. Identify master teachers to coach in years ahead

This third model is clearly the most effective in changing the quality of science teaching and student learning. For instance, in the 3rd year of the program, scores for disadvantaged children on mandated standardized tests increased from 60% to 71% passing. In another school with more economically-advantaged youngsters, but many of them with special needs, scores rose to 84% of students passing the state tests.

But until school districts themselves, with their superior financial resources, adopt the model, it will not be widespread across the students of a continent. That said, the proliferation of our science museums in themselves is a reminder that great ideas catch fire and replicate across the world. These models for increasing the quality of science education can also proliferate as each science museum picks them up, revises them for success in their own region, and expands their use.

Science museums as partners in state initiative for educational transformation

Most science museums/centers in India, especially those under the National Council of Science Museums (NCSM), are public funded institutions and as such are mandated to support formal science education in the country. Consequently, their annual activity calendars have, over the years, evolved to include programs like Science Demonstration Lecture (SDL) and Teacher Training Programs (TTP), which are specifically designed to carry out the museum's school science education agenda. These are now routine activities for Indian science museums/centers.

Whether such activities result in a real-time change in the quality of formal science education is a matter of critical evaluation and debate. But feedback from participants suggests that these activities make at least an immediate impact in the right direction. Although science centers in general are neither programmed to be nor are perceived as serious places for structured science education, which of course is the responsibility of their formal counterparts, the impact of their educational functions - the teacher training program in particular - need to be reflected in the quality of classroom transactions in the formal system. This is essential for public funded institutions like ours if we are to make a mark as agents for positive change in the formal science education set-up and to be considered indispensable entities in the country's education map.

In this context, it is pertinent to note that the National Curriculum Framework (NCF) of 2005 and the Right to Education Act (RTE) of 2009 made it incumbent on the state to usher in certain fundamental shifts in school education philosophy, its pedagogical structure and the quality of classroom transactions. Consequently, the state's education system needed to review and restructure curricular interventions in government schools in a manner that would be consistent with the following core transformational guidelines contained in NCF 2005.

From		To
Teacher-centric classrooms	→	Child-centered learning environments
Transmission of information	→	Construction of knowledge
Knowledge as given and fixed	→	Knowledge as it evolves
Teacher directs, guides and monitors learning	→	Teacher facilitates, supports and encourages learning
Learning by note	→	Learning through activities, exploration & discovery
Disciplinary, linear exposure	→	Multidisciplinary, divergent exposure
Memorizing	→	Understanding

Moreover, RTE 2009, besides making education up to the age of 14 (say, up to 8th standard) a fundamental right for all children in the country, makes the state responsible for ensuring access to equitable quality education across the spectrum of government schools in the country irrespective of their locations - urban or rural.

Together, NCF 2005 and RTE 2009 have certainly opened up new possibilities for Indian science museums/centers, whose educational practices are built on the same basic philosophy, to expand their domain of work and play crucial roles in the transformation of formal science education in the country.

BITM's Initiatives

Birla Industrial & Technological Museum (BITM) in Kolkata, the oldest constituent unit of the National Council of Science Museums (NCSM), has always been known as an educational institution. Besides itself, BITM also controls the operation of another four science centers of NCSM located in different districts of the state of West Bengal. This configuration (Fig.1)

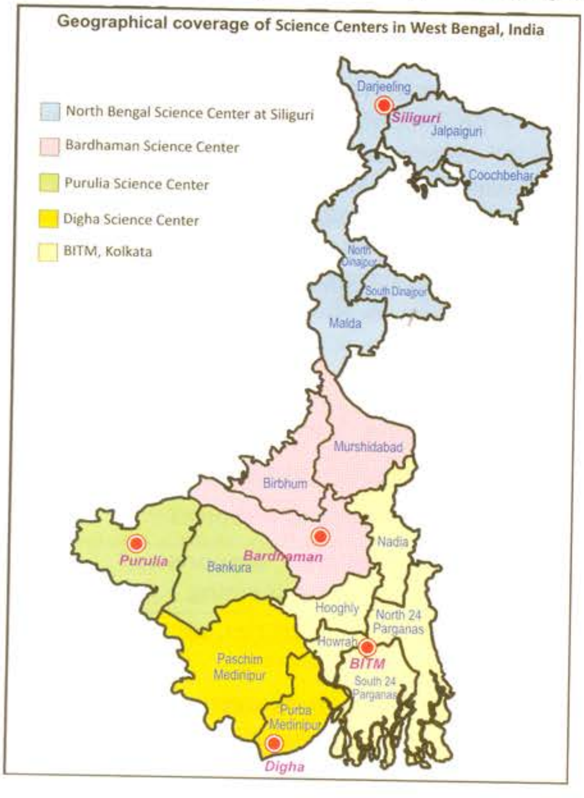

Figure 1: Science centers in West Bengal

gives BITM the requisite structure to carry out its extensive outreach education programs throughout the state often in collaboration with the state's education department.

Thus, when the state needed collaborators to help it implement the NCF & RTE guidelines and establish a child-centered learning regime in government schools, BITM was seen as a natural partner. The role of BITM in this new initiative was to help formulate a roadmap and to implement two pilot programs throughout the state of West Bengal:

1. Activity-based, child-centered learning in primary schools (up to class V)
2. Computer-aided learning in upper primary schools (class VI - VIII)

These initiatives are unique for science museums in India not because they deal with things that are different from the usual, but because these programs involve doing things a lot more differently in regard to their pedagogical structures, logistics and scale of operation. Besides these initiatives, two new facilities at BITM, namely, the Mathematics Gallery (2010) and the Open Science Laboratory (2011) also merit a mention in the context of the core issue of this article.

In this article, however, we will restrict ourselves to a brief description of the first statewide campaign for educational transformation undertaken by BITM and other NCSM science museums/centers in West Bengal in collaboration with the state's education department.

1. Activity-based, child-centered learning regime in primary schools

There are about 50000 primary schools in the state under the government which provide the first step to formal education for a child. Most of these schools are in rural and semi-urban areas spread across the 19 districts of the state. Besides raising these schools' infrastructure to the minimum level prescribed in RTE Act of 2009, the main point of concern and challenge for the administration is to enable these schools to ensure higher enrollment, lower dropouts and better classroom transactions. The task is enormous given the fact that there are funding constraints, infrastructural inadequacies and systemic inertia.

Despite the financial and systemic difficulties, the only way primary education possibly could change and improve in line with NCF & RTE guidelines was through 'capacity building' of the thousands of primary school teachers in the state. To this end, a 3-phase action plan was devised jointly by BITM and the state education department for implementation throughout the state with funding support under the Sarva Siksha Abhiyan (Education for All Initiative) of the government.

1.1 Action Plan

Phase1:Exposure-cum-Educational Visits to Science Centers in West Bengal

Primary schoolchildren and teachers visit science centers on regular basis for making them aware of, and excited about, hands-on activity-based learning.

Phase 2: Training of Primary School Teachers on 'Activity- Based Teaching/Learning'.

Teachers in batches receive 4-day training at BITM and its satellite units in West Bengal on activity-based teaching/learning methods during which they plan co-curricular classroom activities/demonstrations, develop appropriate materials/low-cost teaching aids, and participate in practice classes using the newly developed kits/activities. Teachers take the materials/kits developed during the training to their schools to conduct classroom transactions.

Phase 3: Setting up Activity Centers in Schools

For sustaining the activity-based child-centered teaching/learning practices, small activity centers need to be developed in primary schools which will have basic minimum facilities for creatively engaging the children in 'doing' things collaboratively with the teachers. Trained teachers will use the facility to develop more materials/kits/activities for their classes.

1.2 Implementation

The implementation of the first two phases of the action plan started in mid 2011. It began with students' exposure visits to science centers and was followed by the teacher training component. The idea behind this sequence was to pre-expose the teachers (who would receive training) and their students (ultimate beneficiaries of the training) to the hands-on and self-motivated learning environments of science centers before they started receiving training inputs from these centers.

Responsibility for implementation of the program in all the 19 districts of the state was shared among BITM and its satellite units in the following manner based on their location and infra-structural facility.

	BITM, Kolkata	Bardhaman Science Center	Purulia Science Center	Digha Science Center	North Bengal Science Center
DISTRICT	Kolkata	Burdwan	Purulia	East Medinipur	Malda
	North 24 Parganas	Murshidabad	Bankura	West Medinipur	Uttar Dinajpur
	South 24 Parganas	Birbhum			Dakshin Dinajpur
	Howrah				Darjeeling
	Hooghly				Coochbehar
	Nadia				Jalpaiguri
	6 districts	3 districts	2 districts	2 districts	6 districts

Table1: Districts covered by individual science centers

1.3 Implementation status

The targets for the year 2011-12 were: (i) exposure visits for all students up to class VIII from minimum 5 schools per district and (ii) training of the teachers from these schools. Between May 18, 2011 (when the program took off) and March 31, 2012 (end of plan year 2011-2012), the status of implementation was as follows.

No. of districts covered		No. primary schools included		Beneficiaries	
Exposure visits	Teacher Training	Exposure visits	Teacher Training	Students exposed	Teachers Trained
17	17	183	183	15839	707

Table 2: Implementation status as on 31.03.12

Conducting a statewide program of this magnitude, besides having to deliver museum's regular public programs, was a logistical challenge and demanded careful planning of the individual components. Key issues were:

For Exposure Visits
District-wise scheduling of visits to respective science centers, packaging and delivering tailor-made programs to the visiting children, serving them lunch, and ensuring that they went back excited.

For Teacher Training
Content planning, arranging input materials & tools for teachers to work with, district-wise scheduling of training programs at each science center, arrangement for lunch & tiffin for teachers, and also training of museum staff for the training program.

1.4 Teacher Training Programs : Structure & Content

The duration and batch size of each training program was restricted to 4 days and 35 teachers respectively in view of operational difficulties at the concerned schools as well as at the science centers. While schools could not afford to depute their teachers for more than 4 days, science centers with their limited strength of education staff could hardly do justice with more than 35 teacher trainees at a time. Moreover, larger batch sizes would also have entailed greater challenges regarding logistical provisions - accommodation, transport, and food - for the teacher trainees.

The training program focused on areas the teachers needed to handle in their classes, namely, languages, geography, environment, basic science & astronomy and mathematics. Museum educators, who were to conduct the training, first went through the primary school syllabus for these subjects. In each of them, topics or concepts which the teachers found difficult to transact in their classes through the usual 'chalk & talk' method were chosen as examples for designing training inputs. In order to ensure parity in the training program's deliverables across science centers in the state, concerned museum educators (trainers) from the participating science centers were included as trainees in the first training program at BITM which was conducted by its experienced education staff & officers. The main features of the 4-day training module were:

Goal Orientation & Motivational Inputs
The first half of day-1 was used to orient the teachers towards the ultimate goal of primary education as envisaged in NCF 2005 & RTE 2009 and the role of teachers in making this transformation possible.

The inputs included short video documentaries on 'success stories' by teachers elsewhere and motivational interactive sessions with educationists & state officials.

Image 1: Orientation-cum-motivational session

Image 2: Teachers watching a video documentary

Capacity Building Inputs

Teachers worked in groups under the supervision of museum educators for ideation and development of low-cost classroom exhibits or teaching aids, experiments, puzzles, activities etc. on selected topics in subjects of their choice. Necessary materials, tools and technical guidance (whenever required) were provided by the science center.

Image 3: Teachers working in groups

Image 4: Teachers developing classroom teaching aids

Teachers presented their works and products on the last day before an extended classroom that included museum staff, state officials and fellow teachers from other schools as students.

Image 5: Teachers presenting their works

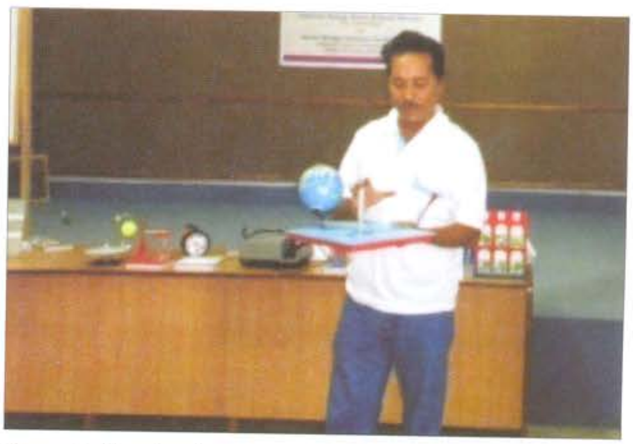

Image 6: Practice classes

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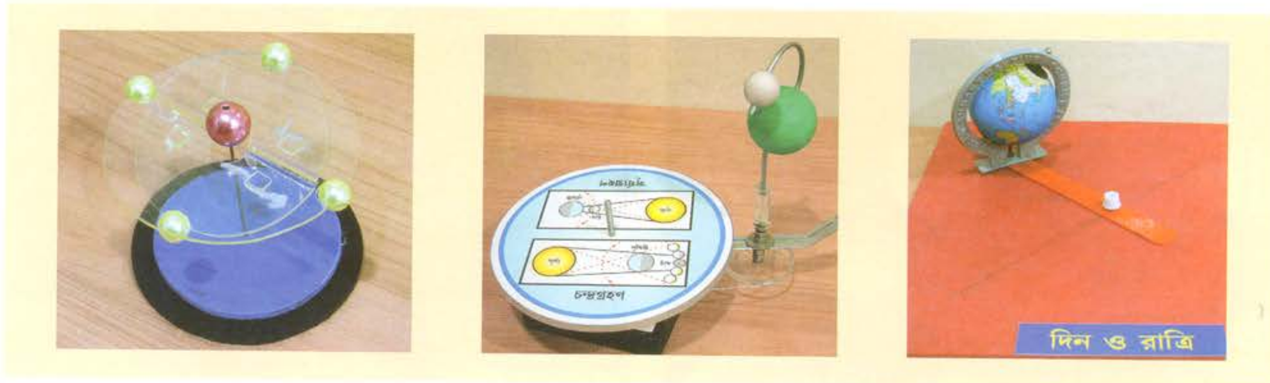


Image 7: Geography teaching aids/kits (for classes III and IV)

Classroom Transaction Inputs

From each school, 4 to 5 teachers joined the program in different batches and they took back all that they had developed during the training. In the process, each of the participating schools got 20 new classroom exhibits, teaching kits, experiments or puzzles, which provided them the basic inventory support to start the hands-on activity-based teaching/learning method. Following are a few samples of the items the teachers developed and took back.

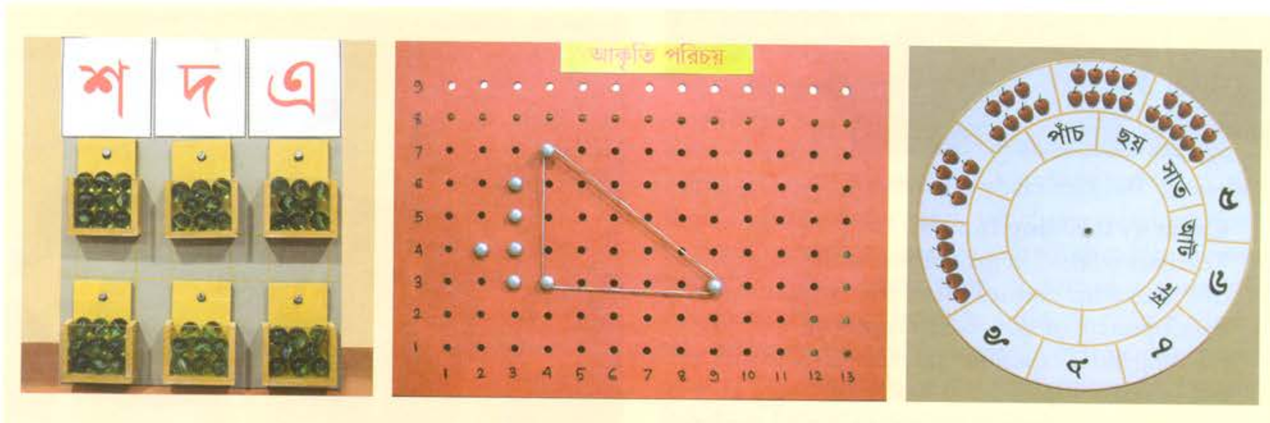


Image 8: Mathematics teaching aids/kits (for class I to IV)

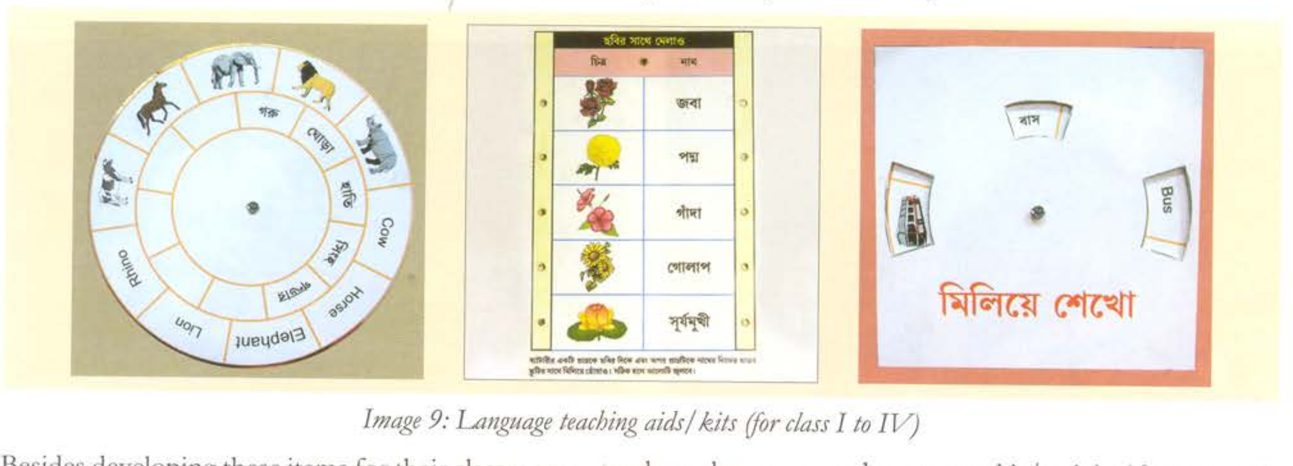


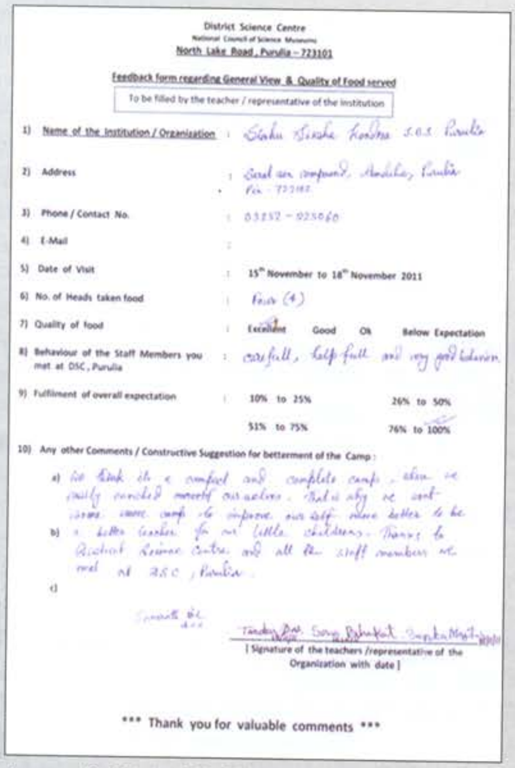
Image 9: Language teaching aids/kits (for class I to IV)

Besides developing these items for their classrooms, teachers also generated many new kit/activity ideas to work on after returning to their schools.

1.5 Feedback

Feedback from each teacher was collected for assessing the quality and appropriateness of:

(a) Logistical arrangements & museum staff services
(b) Training inputs
(c) Classroom kits developed


District Science Centre
National Council of Science Museums
North Lake Road, Purulia - 723101

Feedback form regarding General View & Quality of Food served

To be filled by the teacher / representative of the institution

1) Name of the Institution / Organization : [illegible]
2) Address : [illegible]
3) Phone / Contact No. : [illegible]
4) E-Mail :
5) Date of Visit : 15th November to 18th November 2011
6) No. of Heads taken food : Four (4)
7) Quality of food : Excellent Good Ok Below Expectation
8) Behaviour of the Staff Members you met at DSC, Purulia : carefull, help full and very good behavior
9) Fulfilment of overall expectation : 10% to 25% 26% to 50% 51% to 75% 76% to 100%
10) Any other Comments / Constructive Suggestion for betterment of the Camp :
a) [illegible]
b) [illegible]
c)

[Signature of the teachers /representative of the Organization with date]

*** Thank you for valuable comments ***

Image 10: Typical feedback from teachers

An overwhelming majority of the teachers returned 'excellent grade' for all of these components and felt very positively about the utility of the training program in bettering classroom environment and transactions. A transcript of the typical feedback from the teachers reads like this:

"We think it's a compact and complete camp, where we easily enriched ourselves. That is why we want some more camps like this to improve ourselves to be a better teacher for our little children. Thanks to the science center and all the staff members"

1.6 Sustainabilty issues

Teachers had concerns about the implementation and sustainability of the hand-on, activity-based method of teaching in their schools. Their concerns could be traced back to the issues of

(I) systemic inertia against change
(ii) mission alignment and synergy of purpose among the stakeholders, namely, school's local administration, teachers, parents and the state education authorities
(iii) post-training monitoring, mentoring & funding support

Addressing these concerns will be critical for establishing the child-centered teaching/learning regime in the state on a firm footing. This will require sustained efforts by both the state's formal education establishments and the informal education institutions like science museums/centers operating in the state.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