## An invitation to CUBE – Collaboratively engaging with project-based science experiments

# Learning science by doing science

Meena Kharatmal with CUBE Lab members

Collaboratively Understanding Biology Education (CUBE) at Homi Bhabha Centre for Science Education, (TIFR), is a program engaging students in project-based science experiments in collaboration with Kishore Bharati. The program has a participatory base across the country and the world, with a collaborative working culture to learn the process of science. Students of different age groups, and class/grades work with their peers on hands-on science experiments in school, college and home. CUBE as a frugal lab is developed with the motto of *"Sophistication is not in the equipment but in the minds"*.

Anybody with interest, curiosity and motivation can get involved with the program because CUBE has no selection process, no exam-based entrance, and no fee. Students *learn science by doing science* through research in a non-conventional way. With sophistication in thinking, raising curious questions by observing local events, students connect to frontier level research questions. CUBE is a workspace that can be set up in school, college, or even in a kitchen/ backyard, often without the need for any sophisticated equipment. Easily accessible materials from local surroundings, for example, transparent plastic or glass bottles, tissue papers, water, milk, banana, cucumber, soil, leaf litter, etc., are what you need to start.

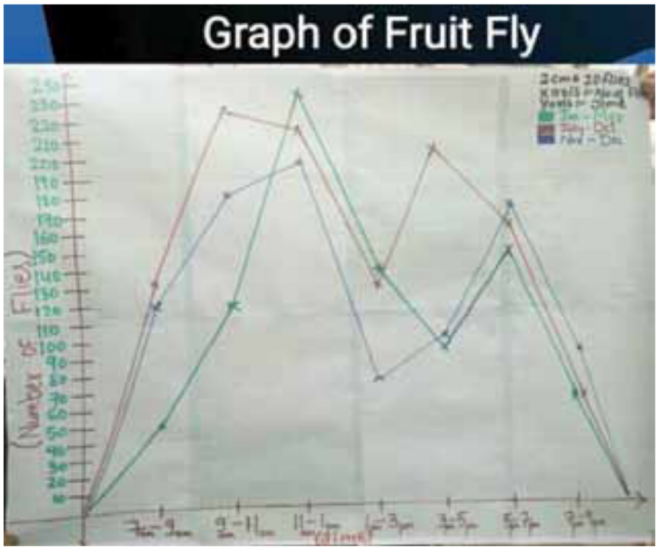
Students are continuously engaged in discussion with their peers, teachers, scientists across the country via social media, such as WhatsApp, Telegram, E-mail, Facebook and Twitter. They enthusiastically discuss about their experiments, goof-ups, mistakes, errors, results, the design of the experiments, etc. This facilitates discussion not only of the scientific process, but also engages everyone by giving quick feedback.

CUBE has done experiments with a variety of model organisms like fruit fly, earthworm, snail, moina, butterfly, hydra, rotifer, nematode, etc., in a very simple and effective manner. Students also have the opportunity to observe, using a microscope, while performing these experiments. They engage in research questions in each of the model organisms, for example, "What is the pattern of the day and night cycle followed by fruitflies?"; "How rapidly can the nerve chord regeneration occur in earthworms?" These research questions, are often raised by their own curiosity or by observing the surroundings. Notably, these research questions connect with the frontier level research. For example, stem cell research, genetics, epigenetics, learning and memory, reproduction, evolution, climate change, etc., are linked to their experiments. These areas have been the focus of Nobel Prize winning research. In fact, when the Nobel Prizes are announced, students feel happy to see their area of research winning Nobel prizes. In the recent past, at least two Nobel Prize winning works have been on – discoveries of molecular mechanisms that control the biological clock (being studied on the fruitfly in the CUBE lab); discovering how cells detect oxygen, react to hypoxia condition during low concentration of oxygen (being studied on moina in the CUBE lab). As an illustration, we present two experiments on the fruitfly and moina model organisms, that incidentally are also related to Nobel Prize winning discoveries.

The first experiment is about "understanding the day and night cycle in fruitflies". Fruitfly is a model organism found in our local area. Simple things that are easily available are required for the experiment –

Photos courtesy: Meena Kharatmal

*CUBE Conference Participants – a mix of school, college students working in collaboration.*



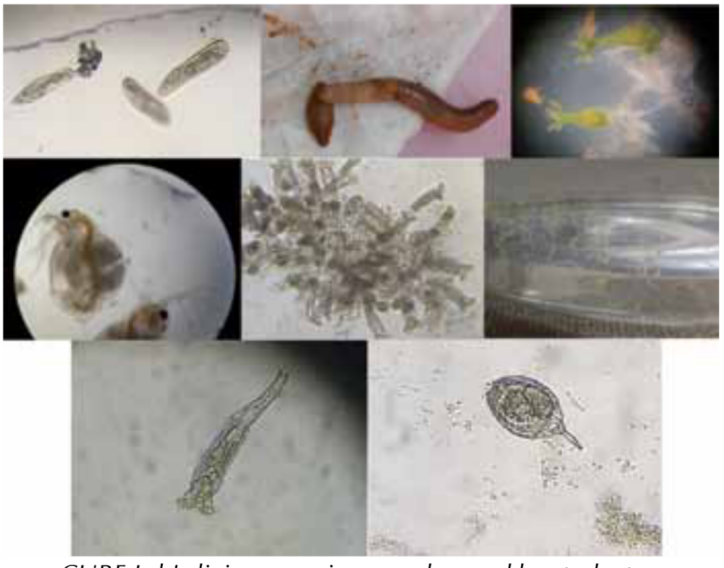

*A graph of students' observation of observing circadian rhythm in fruitfly over a period of one year.*

a transparent plastic or glass bottle, banana, banana peel, cotton ball and a notebook, that's all! A small piece of banana and/or a banana peel is placed inside a transparent bottle and is kept in the kitchen or garden so that fruitflies are attracted by the smell of the fruit. Observe the bottle for at least half an hour. It may contain fruitflies. The bottle is then covered with a cotton swab so that the fruitflies do not fly away. Students can record their observations on the time and the number of fruitflies that were found in the bottle. They can observe the flies at two- hour intervals, over a few days, using different bottles. In fact, students can also observe their life cycle. Once students observe the time and the number of fruitflies trapped in the bottle, they generate a log, tabulate their observations, and plot graphs in their notebooks. In their studies, students have found that fruitflies are active during the day. Through this simple experiment, students can understand the day-night cycle (circadian rhythm, biological clock), that is also followed in humans. In fact, students were excited to know when they realized that the Nobel Prize for medicine and physiology in 2017 was announced for the same area that they have been investigating with the fruitfly.

Another experiment is about "understanding the role of oxygen in the moina." Moina is a transparent micro-organism. It is easily found in stagnant water or ponds. About 20-25 moinas can be kept alive in water in a transparent plastic or glass bottle. Because the moina is transparent, students can easily observe their movements, heartbeat, and even while they produce their offspring. If we focus a flashlight on the moina in the bottle, all moinas are attracted towards the light. This behaviour is called phototaxis, i.e., an organism's ability to move towards a light source. Moinas in the CUBE lab are being studied to observe the changes and effect of oxygen and lack of oxygen on their haemoglobin production. Haemoglobin is a protein molecule in red blood cells that carries oxygen. In the transparent bottle, students feed the moinas with 1-2 drops of milk, and observe it daily. Increasing the amount of milk affects the amount of oxygen. As a response to the variation in the oxygen concentration, the moinas change their colour from transparent to red, and because haemoglobin is produced, the colour appears red. Further, it is also interesting to see the red moinas turning back to transparent when the oxygen level is maintained; this process is called, normoxia. Students keep a log, record and tabulate their observations regarding drops of milks, number of days in which transparent moina turned red, etc., in their notebook on a daily basis. Scientists who have been studying how cellular systems work to detect oxygen levels and its effects on human life processes were awarded the Nobel Prize in 2019.

Students often enjoy catching earthworms during the rainy season! These earthworms are friendly beings for the environment and farmers too. In the CUBE lab, students managed to create a compost pit of earthworms captured from local surroundings. Students use these earthworms to study their behaviour. School students have collaboratively worked on an experiment with a simple design, using earthworms and salt solution to study their rapid escape response. In fact this behavioural response is studied in the context of the earthworm's ventral nerve chord and its regeneration. A transparent plastic cup which has holes in its base is used. Wet pieces of tissue papers are added and earthworms are cultured in the cups. Using this cup culture, students connect with the topics of respiration and digestion.

Another exciting project is called "Pagalapos" inspired by Charles Darwin's study on diversity of living



*CUBE Lab's living organisms as observed by students – Paramecia, Earthworm, Hydra, Moina, Rotifer colony, Hydra colony, Bdelloid Rotifer, Rotifer.*

*Context Maps created by students in a CUBE Conference.*

organisms on the Galapagos islands. The Pagalapos are pits of water surrounded by land pieces, often seen during the rainy season. The pagalapos is a project to study the diversity of micro-organisms at our doorstep! Using simple methods, students collect soil samples and observe life forms under the microscope. In fact, this is also one of the activities mentioned in class 8 textbooks. Students are always excited to observe various living micro-organisms such as paramaecium, rotifers, etc., in a drop of soil sample.

CUBE students often use this project to estimate and measure the size of micro-organisms in microns, which otherwise is difficult to understand.

Yet another example is of culturing hydra by feeding moina. Usually in research, the protocol followed is to feed hydra with artemia culture which itself is tedious and expensive. The CUBE lab managed to bypass this protocol by using an innovative simple method. Students culture hydra in a beaker with dechlorinated water (bucket full of tap water kept in the open for a day) by feeding them with moina (a fresh water model organism from the CUBE lab). Often, students confuse hydra for a plant due to its green colour. The chlorohydra is green due to the presence of chlorella algae inside it. This becomes an interesting discussion regarding plants and animal classification for school


*CUBE centres across the country*

*School students working on simple experiments, discussing, presenting their work in CUBE conference.*

students. Hydra is used for studying symbiosis, classification, regeneration in the CUBE lab.

During major festival holidays, CUBE lab conducts workshops. Students work in groups on experiments for 1-2 weeks continuously, or work on an ongoing experiment. A full day conference (CUBE Conference) is held on the last day of the workshop to give the students an experience to present their experiments.

Additionally, CUBE also conducts citizen science programs. For example, a mango mapping study, wherein citizens (members of the public) map the blossoming of leaves, flowers and fruits from different states. At the time of state and national election periods, the use of indelible ink on the fingernail is an opportunity to study nail regeneration. During the monsoon, even mosquito mapping becomes relevant.

Currently the CUBE lab members are Prof. Nagarjuna G, Prof. M. C. Arunan, Shri. Mayur Gaikwad, Shri. Ashutosh Mule, Shri. Jaikishan Advani, Ms. Kiran Yadav, Ms. Meena Kharatmal.

To set up a CUBE lab in schools, interested teachers can write to us at cube@hbcse.tifr.res.in. To know more about the CUBE program visit the website https://www.gnowledge.org/projects/cube.html. To participate in the chatShaala, visit https://metastudio.org/ and also get engaged in daily discussion through https://webinar.hbcse.tifr.res.in/b/kir-vgc-6jf

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